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SINKING A SHAFT THROUGH LOOSE MATERIAL.

METHOD EMPLOYED SUCCESSFULLY AT THE "TILLY FOSTER" MINE.

BY A. McC. PARKER, E.M.

FIG. 1, Pl. 1 gives the general outline of a section taken through the center line of the shaft. It will be seen that one of the chief dangers to the sinking of the shaft lay in its nearness to the retaining wall shown on the section, which held in place the mass of broken rock, dirt and debris, through which it was necessary to sink, and any movement of the mass must of necessity carry out the wall. Accordingly a pit 8 x 10 feet at the bottom was dug in the top of the heap as deep as could be without the sides caving in, and in the bottom of this pit a shaft set made of round oak sticks 10 inches at the butt, was laid at an angle of about 80° with the dip of the foot wall. Stulls were then cut from this set 4 feet long, on top of it was placed a second set, and so on up for another set, until the level of the plat was reached. The timbering then consisted of a frame the size of the shaft, but unplanked. Two-inch oak plank, not over 9 inches wide, were then driven under the caps of the upper sets and over the caps of the lower as far as they could be driven, after which the dirt was filled in around the top of the shaft, a levelling set put on, and the top planked over and rigged with a windlass. This stage of the work is shown in Pl. 1, Fig. 2.

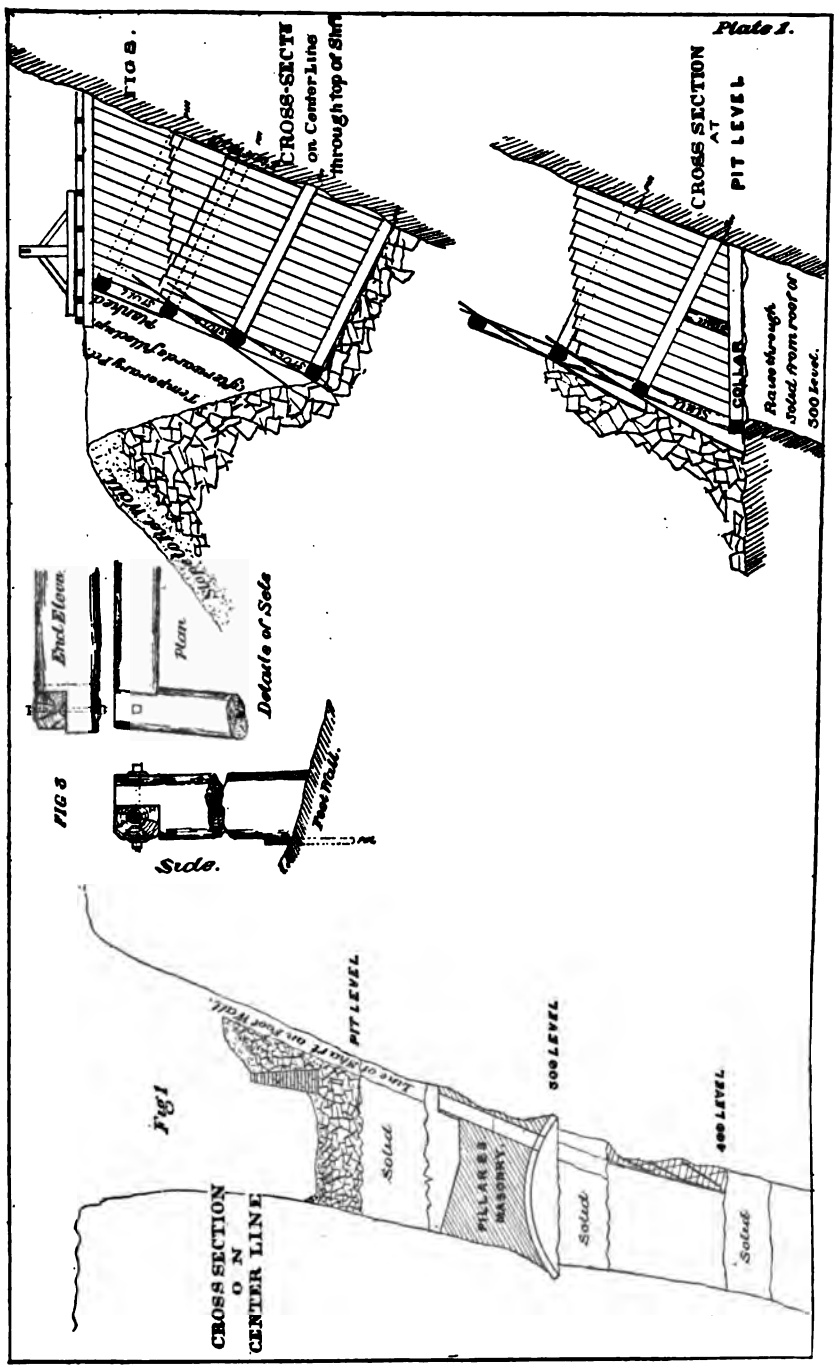
Plate 1.
CROSS SECTION AT PIT LEVEL
COLLAR
TIMBER
Raise through Solid from roof of 300 level.
FIG 8.
CROSS-SECTION on Center Line through top of Shaft
Temporary Shaft
Solid
Timber
Detail of Sets
Back Elevation
Plan
FIG 8
Side.
Foot Wall.
Fig1
CROSS SECTION ON CENTER LINE
PIT LEVEL
300 LEVEL
400 LEVEL
Line of Slope from Foot Wall
Solid
PILLAR OF MASONRY
Solid
Solid

The lower row of planks were then driven, one at a time all round, and as fast as they were down, the dirt and rock inside the shaft was hoisted, until about six feet had been excavated, when another set was placed and a new row of planking started, the set being supported on short blocks, or often resting on the dirt at the cap end. When about 35 feet had been sunk, the top of the retaining wall gave way and slid out into the pit, carrying about 15 feet of the shaft with it, but leaving the bottom intact. This, fortunately occurred in winter, just after a thaw, when the whole mass was thoroughly wet. The shaft was then allowed to stand until a cold snap should come, and in the meantime a new wall was built outside the old one, strong enough to stand, and by the time this was up the whole mass of loose material was frozen solid. The top of the shaft was then opened, a new collar and four sets put on, first having put on a levelling set that extended two feet beyond the original set, to rest on the dirt, the whole top double planked with two-inch oak plank, the pit filled in and tamped, and all was ready to try again.

The details of the sets are shown in Pl. 1, Fig. 3. The caps and legs were flatted on two sides only, the cap was then notched half through at each end and a shoulder one inch wide was squared off on the end of each leg. The corresponding notch on the legs was cut so that the cap and legs went together and the one-inch shoulder on the leg bore its whole length on the cap. The legs were then cut to fit the foot wall and the right length to bring the cap out to line, after which the cap was bolted on by a ¾-inch bolt, a 1¼-inch iron pin let in to the foot wall, supporting the foot of the leg on the wall.

When the plank were driven they bore against the dirt on the outside of the cap of a lower set, tending to crowd it towards the wall, and on the inside of an upper set. This last pull was resisted by the dirt and the thrust of the planking on the other side of the cap, and consequently the harder the plank were driven the stronger the shaft became.

The sets were partly supported by the friction of the planking against them and partly by setting them not normal to the dip of the shaft, but at an angle considerably above the normal, so that as they tended to slip down at the cap end they became longer in a direction normal to the dip and consequently exerted a thrust against the overlying dirt, which was practically solid because of

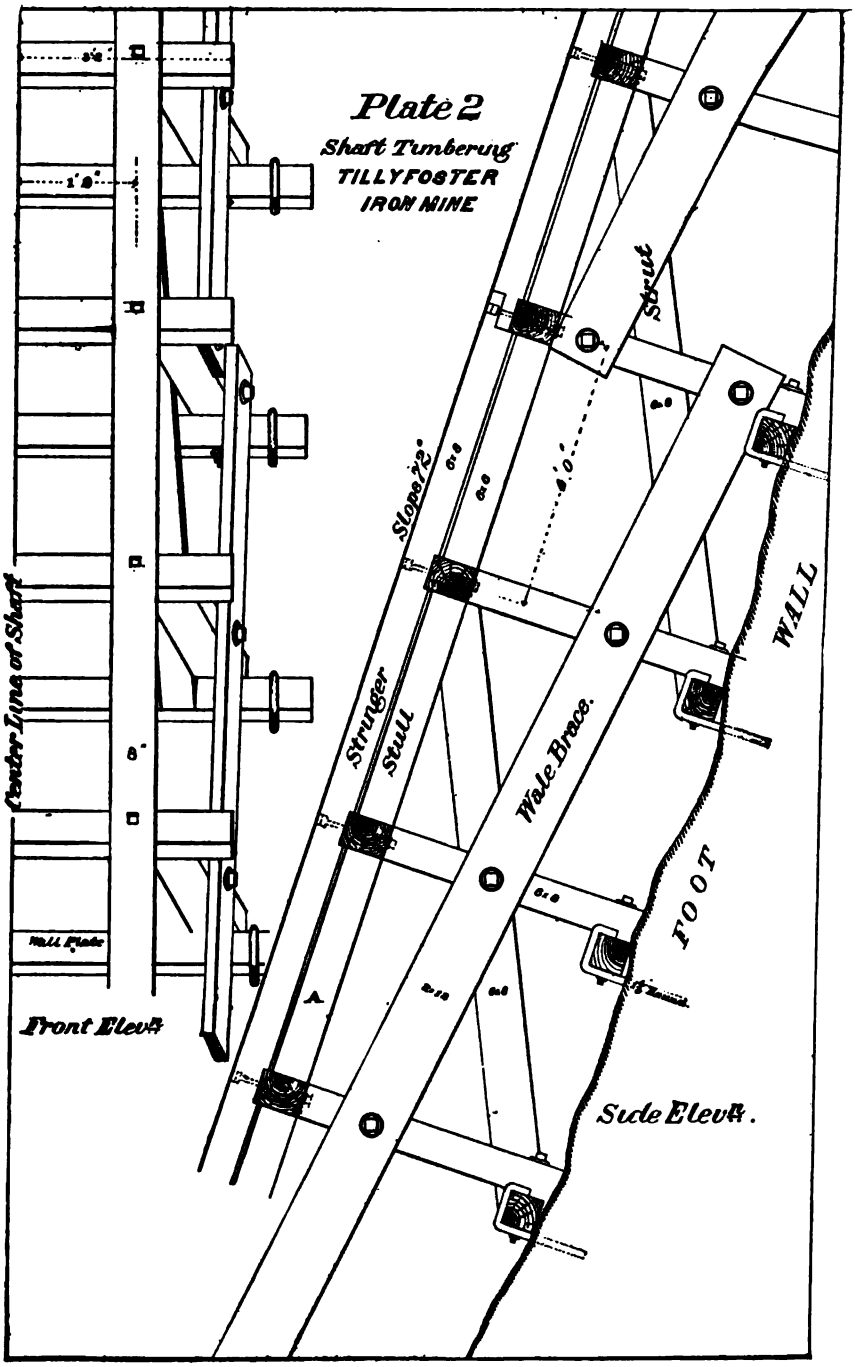
Plate 2
Shaft Timbering
TILLYFOSTER
IRON MINE
Strut
Slope 72°
Stringer
Stull
Wale Brace.
WALL
FOOT
Centre Line of Shaft
Wall Plate
Front Elevn
Side Elevn.

the frost. No trouble was encountered on this score, however, and gradually, without further mishap the excavation passed through boulders, fine stuff, large masses, etc., until it reached the solid bottom of the pit, the shaft having previously been raised in this solid from the roof of the 300-foot level, leaving a cap of four feet over it. When the solid was reached, coming down, this cap was broken out, and after trimming down and enlarging the opening all was ready to secure the temporary shaft. A beginning was made by levelling off the floor of the pit around the opening, and putting on a heavy oak collar, framed as were the other sets. Stulls were then cut from the ends of the cap to the ends of the cap of the set above, and one on each side about the middle of the legs. These were wedged solid. After carrying up about four sets we began at the bottom set and wedged it all around on the under side until no more could be driven. The planking last put in was then driven as far as it would go, when the ends of the plank were cut off just under the cap against which they bore on the inside, and without any trouble, owing to the spring in the plank, their ends could be forced outside the line of the caps. This alternate stulling and cutting of the planking was carried up to the top and when completed the shaft was solid and double planked with two-inch oak plank. But little dirt came into the shaft through the joints in the planking, and the progress made was quite satisfactory, about a foot a day being sunk with a single shift of five men.

As this shaft was to be part of the shaft built in pillar 2, south (see article on Masonry Supports, etc., of the Tilly Foster Mine, *School of Mines Quarterly*, May, 1885), it may be well to describe the system of timbering used in going from the 400 level to the 300 level in room 2, south, climbing up the footwall to connect with the piece built in the masonry. A track was to be carried up on a 3½ foot gauge. The caps of the sets were made 6 feet 4 inches long, and the timber used was 6 x 8 inch spruce. Two inches to the foot was the flare adopted for the legs, and they were tenoned into the caps with heavy tenons the full width of the legs. The legs were fastened to the foot wall by means of ¾-inch bolts running through their ends, which butted on and were cut to fit the wall, and through 6 x 6 inch or 6 x 8 inch sticks that lay on the foot wall as nearly as possible, held to the wall by 1¼-inch round iron cramps, let 16 inches into drill holes and well wedged. After the first set at the 400 level was in place, normal to the dip

of the shaft, stulls 3 feet 6 inches long (A. Pl. 2) were cut and put on the cap over the tenons, and spiked. Temporary stulls were similarly placed near the sill ends of the legs and the measure taken for the second pair of legs. They were then cut off, cut to fit the foot wall, the cap put on and the legs bolted to the piece on the foot wall, and so on up.

The next step was putting on the stringers, which were placed 3 feet 4 inches between centers, laid on the flat and cut 20 feet long. They were notched down to five inches where they went on the caps and locked on each cap. Five-eighth inch bolts were run through at each intersection, with heavy washers, and the whole set up snug. After this much was accomplished, long 6 x 6 inch struts were cut from the cap of each third set to the stick cramped to the foot wall on the inside of the corresponding set below. On the outside of the sets 2 x 12 inch spruce plank 18 feet long were used as wale braces, running from the sill of one set gradually to the cap of the fourth set below, and bolted at each intersection with the legs. The result is a shaft, very stiff laterally and vertically, while the time required to erect it was very short.

Any one piece can be readily taken out and replaced, and repairs made at any time.

ON FLINT'S INVESTIGATION OF THE NICARAGUAN WOODS.*

BY R. H. THURSTON, DIRECTOR OF SIBLEY COLLEGE OF CORNELL UNIVERSITY.

PRELIMINARY REMARKS. BY R. H. THURSTON.—It had long been a conviction of the writer that the tropical and semi-tropical countries of America possess a large number of valuable timber trees of which nothing is known by our engineers or builders, but which, for some of the more important purposes, as well as for ornamental and exceptional constructions, may have extraordinary value. As the process of stripping our own land of timber goes

* Presented to the American Association for Advancement of Science, New York Meeting, August, 1887.

on, and as our pines and finer grades of timber trees become gradually more and more difficult and costly of procurement, the necessity will become more and more pressing of going into the more heavily forested countries nearer the equator for our supplies of lumber. It is thus becoming continually more important that we learn something of the resources of such countries, and especially of the useful qualities of the woods available for building purposes. The knowledge of the extraordinary strength, and of the other valuable properties of some of these timbers will unquestionably, in time, lead to the opening of our markets to them, and to a trade that may prove to be of inestimable advantage to both purchaser and vendor. A few years more will see the great forests of the Northwest stripped of their best timber, and the supply will then be mainly drawn from the South and the Pacific Coast; but the enormous rate of growth of the country in population, and still more in manufactures, will sweep those districts clean at a rapidly increasing rate of destruction, and it will be found, probably much sooner than is now generally imagined, that we must look elsewhere for the enormous supplies demanded by our markets. The growth of this demand is a geometrical one.

That most remarkable of recent works on economical subjects, that romance of statistics, *Triumphant Democracy*, gives some striking facts abstracted from the last census. Mr. Carnegie finds that our lumber trade has quadrupled within the generation, the business now employing about 150,000 men, and producing nearly $250,000,000 worth of lumber. About $40,000,000 is invested in this trade in Michigan alone, and the three states, Michigan, Minnesota and Wisconsin cut, in the year 1880, over 7,000,000,000 feet of timber, in the form of marketable lumber, besides millions of feet in the shape of railroad ties and other minor products. It is estimated that the pine forests of the Northwest will be gone in about twenty or twenty-five years; but the southern forests are of much greater extent. It is not certain that we shall very soon be entirely deprived of the light and comparatively soft growing woods; but their extinction would seem to be but a matter of time, and, as the lives of nations are counted, not a long time.

Mr. Jessup has collected for the New York Museum of Natural History some 400 varieties of North American woods, including very many which are of very great value for constructive purposes; some of these, as the sycamore, have not been as yet much used,

but are now being found to have peculiar value for special purposes. The consumption of these hitherto neglected timbers will continually and rapidly increase. Others, as the live oak of our Gulf States, have been used exclusively for special purposes, as in shipbuilding, and have, by the progress of improvement in the art, been thrown out of use, to come in again at some later time in a way as yet unforeseen. The soft woods from their cheapness, and especially from the ease with which they can be worked, are in greatest demand, and, fortunately, they are those which have hitherto been most plentiful and cheap in our markets; but they are gradually becoming less accessible and more difficult of procurement, their cost is thus threatening to become seriously increased, and we are likely to be compelled to find ways of substituting the hard woods for the soft in our constructions. A century ago, oak was the most common of building timbers in the older countries of the world; it seems now possible that it, and the other hard woods, may, in time, again come into general use; but, if so, we must after a time, go into the Southern and neighboring states for such woods. Once we are brought to the use of such hard woods again, we shall perforce, be brought to the construction of buildings capable of withstanding the teeth of time as effectively as did those of our ancestors of the middle ages.

We are to-day sending out into the markets of the world, annually, something like $30,000,000 worth, probably, of wood, in the form of manufactured articles mainly, particularly as furniture, and the time is coming when we shall supply a very large part of the world with its timber and manufactured wood products; but this will only hasten the day when we must look to the West Indies and to Central and Western America, perhaps to South America, for our own supplies.

It was considerations such as have been above outlined that led the writer, some years ago, to endeavor to secure such data relative to the useful qualities of the tropical and semi-tropical woods as would, in the course of time, prove useful to our own people as well as to the citizens of those neighboring countries to which we shall be likely to first look for our supplies of the heavier sorts of timber; for it will be seen that nearly all of the semi-tropical and tropical woods are of the harder varieties and are distinguished rather by their hardness and strength than by lightness and ease of working, the peculiar qualities of the varieties of the coniferæ

from which we obtain the greater part of our timber to-day. The first attempt to investigate these hard woods of the warmer latitudes in a systematic and satisfactory manner was probably that undertaken some ten or fifteen years ago by French engineers and naturalists studying the trees of New Caledonia. Later investigations of a similar character have been made, usually since the work directed by the writer about to be referred to as initiating his own researches, by British authorities, in India and in the Australasian colonies of Great Britain. The first systematic study of these classes of woods in America, so far as the writer has observed, was made at the suggestion and request of the writer by Mr. E. D. Estrada and published in Van Nostrand's *Magazine* for November and December, 1883. Recently, another investigation has been undertaken in the Mechanical Laboratory of the Sibley College, Cornell University, by Mr. Rufus Flint, the results of which will here be presented. Mr. Flint, although by descent on the father's side an American, is a native of Nicaragua, and, until coming into the United States to obtain his education, has been a resident of that country. Through his relatives and friends, and assisted by the liberality of the Government, which allows such material to enter duty free, Mr. Flint has been able to secure a fine collection of the woods of Nicaragua, and thus to enter upon a research as important in its bearing upon the business interests of his own country and of the United States as that conducted by Mr. Estrada.

Examining the data thus secured by these investigators, we find that the tropical woods are distinguished by their extraordinary strength, elasticity, beauty of grain and durability. The few already known to us, such as mahogany, rosewood, and some of the cedars, may be taken as illustrations of the several principal classes of timbers to be found in the forests of Central America, and the Islands of the Caribbean Sea. These woods are all coming into demand very rapidly already for house decoration, and in the construction of the finer grades of furniture, and an examination of the magnificent collection gathered at New York, by Mr. Jessup, will reveal the fact that we have but begun to make application of the enormous variety of woods which are readily obtainable and available for such purposes. These statements will be seen to be true of the woods of Central America here to be described, as well as of the Cuban woods already reported upon.

In both cases, but a few of an immense number of woods have been taken for investigation; but these selected samples may be taken as illustrative of the whole product of this vast arboretum. The tropical trees attain enormous sizes, are extraordinarily solid, close and firm of grain, excel in the beauty and variety of their coloring, in fineness of textures, and especially in their wonderful durability, whether exposed to the corroding influence of the atmosphere, to the action of heat and moisture, or to the attacks of insects. Ironwood and lignum vitæ exemplify the first of these characteristics; mahogany, rosewood, tulipwood, and others, illustrate their beautiful color and grain; and the live oak and teak are good examples of their power of resisting the action of oxygen and the attacks of the teredo and of the limnoria.

The investigations of the Central American woods were made in the several testing machines and the workshops of the Sibley College, and the results were reported to the writer in a paper presented in June last, the substance of which is here given. The report is so well written and so complete that it has been thought best to give the whole in the words of the observer. The figures have been very carefully checked, and are believed to be perfectly reliable throughout. The machines used had been standardized and were known to be practically exact, and it is thought that the data thus obtained, as here given, may be of real value to the profession, as well as to the two countries most nearly interested in the results of the research. The native nomenclature is given throughout. It was found difficult to obtain the botanical names of all these woods, and, in many cases, those obtained were subject to some question in consequence of the fact that the botanists seem to have had comparatively few opportunities of study of these woods; but the introduction of the timbers of these regions into our own markets will undoubtedly lead to the adoption of the nomenclature obtained in their homes, and no inconvenience will arise, it is thought, from the omission of the technical names.

The examination of the Cuban woods, to which reference has been made, showed moduli of elasticity as deduced from the experiments on transverse stress and strain, varying from 1,500,000 to 2,500,000, British measure, the great majority of the dozen and a half varieties studied ranging above 2,000,000 or equalling the

stiffness of the Indian teak, and exceeding that of any known variety of our native timber, with the exception of an occasional sample of the strongest and stiffest of the choicest of Southern, long-leaved, yellow pine. The figures for the best of the Cuban woods are above those of any known North American woods, exceeding their best figures by fifty per cent., nearly. Three-fourths of them are stiffer than the best teak. The moduli of rupture by transverse stress vary between 15,000 and 20,000 pounds per square inch, as a rule, in but one case falling to 8000, and in several exceeding 20,000, the average being not far from 18,000. The densities average above that of water, and many samples exceed that unit by some twenty per cent. Quite a number of these woods have just the qualities which distinguish yellow pine of the finer grades; for example, Baria (*Cordia gerascanthoides*) and Caobilla (*Crotos lucidam*) as representing the lighter varieties, and Majagua (*Paritium elatum*), an even lighter and stronger wood; Dagame (*Colycophyllum candidissimum*), one of the most common of West Indian woods, weighing but fifty-six pounds per cubic foot, and having a modulus of rupture of 16,000 pounds.

Sabicu (*Mimosa adorantissima*) has just the weight of water, or a trifle less, and, with a modulus of elasticity of about 2,400,000, exhibits a modulus of rupture exceeding 20,000. A dozen of these varieties are higher in rank than the best building material found in our native forests.

The Central American woods, growing on a more widely distributed area, in a soil of less uniform character and in a greater variety of climate, are naturally of more widely differing character than those of Cuba. The high and dry atmosphere and more innutritious soil of the interior, and the rich bottom lands of the swampy regions of the coast, with every intermediate condition of soil, climate and exposure, produce timber of soft as well as hard varieties, of less as well as of greater strength or elasticity, and thus yield to the market a larger assortment of useful woods than could any insular district. The moduli of rupture, as determined by Mr. Flint, vary from 7000 to nearly 30,000, and the moduli of elasticity from about 600,000 to about 2,500,000, usually approximating 2,000,000, the modulus of rupture commonly falling at about 22,000.

NICARAGUAN WOODS.

An Investigation of the Strength and Other Properties of some of the Nicaraguan Woods used in Engineering Construction and in the Arts, conducted in the Mechanical Laboratory of Sibley College of Mechanical Engineering, Cornell University, by RUFUS FLINT, M.E.

INTRODUCTION.

The woods of Nicaragua, grown under the sunny sky of the torrid zone, and in the mountains, valleys, and on the sandy shores of the Atlantic and Pacific Oceans, are many in number and of widely different character in nature, strength and color. Unrestricted in their growth, in the exuberant and wild forests and woods of the country they attain enormous sizes, and exhibit great strength and solidity.

As a general rule, they are of delicate hues and beautiful colors, exhibit extreme fineness of grain, and have marked peculiarities in texture and general appearance.

The investigation of their strength and natural properties is a matter of great interest. With the facilities offered in the Mechanical Laboratory of Sibley College for complete investigation of the materials of construction, I have thought it advisable to conduct such an investigation of a few of the Nicaraguan woods, so as to make known the characteristics, not only of those that have found their way into the markets of this country and of Europe, mainly because of their worth as dye woods or for ornament, but also of some others, perhaps of better if not equally prized properties, which have yet remained unknown in the industries.

In undertaking this investigation, I hope to find results which may prove of value and interest to the artisans of my native land, and also aid in developing, to a certain extent, the commerce and industries of Nicaragua, by making some of its natural products known in the United States and Europe.

I have restricted myself to the study of those woods which are most used in engineering construction and decoration, leaving out the dye and other woods, which, perhaps, may be of equal

interest and value, there being quite as many unknown, or at least unused, valuable woods and plants of this latter kind.

Encouraged from the start by Professor Thurston, he very kindly wrote to the Government of Nicaragua asking for a collection of the most important woods of the country, expecting that its officials would take, or at least show, some interest, and thus secure a good collection of the woods. But unfortunately we were in this disappointed. It was by my father's interest, kindness and persistence, and through my friend Miguel Ugarte's active and courteous help that I was supplied with as good a collection as could be obtained in the short time allowed. Steps were taken to get the woods seasoned and sound, from persons engaged in working them, but they failed to obtain them. It is for this reason that the woods tested have not been entirely satisfactory, as they were cut green, and the men could not in most cases fell large trees to get the heart or the best of the wood; as a consequence they checked on the way, and many of them were found to be knotty. The woods were collected in one month, within a circuit of three leagues, on the hills about Belen, in the agricultural and chocolate-raising "Departmento" of Rivas, between Lake Nicaragua and the Pacific Ocean. Some few, obtained from a carpenter, are seasoned. My collection of fifty different varieties represent about half the number of the useful woods of the country.

The terms used may be thus defined: the modulus of rupture for tension is the force necessary to pull asunder a bar whose section is one square inch, when acting in the direction of the axis of the bar.

The modulus of rupture for compression is the pressure necessary to crush a piece of any material whose section is unity and whose length does not exceed above five times its diameter.

The modulus of rupture for transverse stress is the stress at the instant of rupture upon a unit of the section which is most remote from the neutral axis on the side which first ruptures.

The modulus of elasticity is a value which expresses the relation between the extension, compression or other deformation of a bar and the force which produces the deformation.

Resilience is a measure of the capacity of a material to resist shock, and its value is equal to the amount of energy expended or the "work" performed in producing distortion or rupture.

GENERAL DESCRIPTION OF THE WOODS.

(1.) *Carbon.*—Extraordinarily solid, equalled only by the Piedra and the Quiebra-hacha. Is almost imperishable when used for posts, and is supposed to be very good for railroad ties. The tree attains a height of 30 feet and measures 12 inches in diameter. Is common in most of the wooded districts. The wood is of a very fine grain, with peculiar dark streaks, very much like the mahogany in appearance and in color, but heavier and much handsomer. Is easy of working and turns very smoothly.

(2.) *Cedro* (Cedar).—The wood, on account of its peculiar properties, has found a place in all the markets abroad. In Nicaragua it is found abundantly, and attains enormous sizes. Is used extensively for furniture, frames, book-cases, etc. It is even used by the Indians for boats, which they work out entire from the trunk of the tree.

(3.) *Chaperno.*—Dark red color, turns and planes very smoothly. It has a fine grain and great strength, and is susceptible of high polish. It is used extensively for cross-pieces of drawers and tables. Is extremely durable. There are two varieties of this wood, black and white, as they are called respectively. The tree attains a height of 40 feet.

(4.) *Chiquirin.*—Dark yellowish wood, with a strong cedar smell. Is heavy, fine-grained, and planes smoothly. The tree attains a height of 30 feet, and 1 foot in diameter. It has various uses, is durable and, having odor, is probably not subject to attacks by insects.

(5.) *Cortez.*—Extremely heavy and very fine-grained, of a very dark yellowish color. When broken in splinters it gives off a fine yellow powder, which has similar properties to litmus; it turns bright red when mixed with soap water. It is a large tree, like the Nacascolo. It is used in cabinet work, for framing, etc. The only place in which I can remember to have seen it growing is on a rocky hill at the foot of the volcano Mombacho, near the shore of Lake Nicaragua. The hill is covered with these trees, which, in the beginning of every spring, are a beautiful sight, being covered with yellow flowers.

(6.) *Granadillo-negro.*—Wood very much esteemed for interior decoration on account of its handsome dark color, fineness of grain and ease of working. The tree attains a height of 30 feet, and is

found on the shores of the rivers which flow into the eastern side of Lake Nicaragua.

(7.) *Guachipilin.*—Fine-grained wood of a light yellowish color, heavy and tough. The tree attains a height of 30 or 40 feet, and has a diameter of 15 inches. It is irregularly branched. Much used by the artisans for durable work, as it resists moisture for years. It is also used for telegraph poles and railroad ties. Is abundant all over the country.

(8.) *Guapinol.*—The tree is nearly as large as the Jenisero, and its branches large but more erect. The wood is of a light mahogany color, long-grained, but very compact, heavy and tough. Is used almost exclusively for cylinders of sugar-cane mills, while the teeth moving them are made of guachipilin, guayacan or other similar wood.

(9.) *Guayabo de Monte.*—Attains a height of 60 feet, is of irregular diameter, and seldom over 2 feet above the lateral root, acting as braces, which support the trunk. It has a fine grain and is very tenacious. The test made probably does not show full strength, as it was an inferior sample. It is used for small masts and the weather streaks of boats. According to Mr. D. L. Murray, who preferred it above all others for launch guards, it resists wear and tear better than any other wood.

(10.) *Guiliguiste.*—A wood unknown to commerce. Has a light brown color in the heart, is fine and fibrous of grain. It ran above the average in compression. It is not as durable as the other hard woods, but from its beautiful grain and color and from its ease of working it would seem that it should be used for interior house work. The tree is small, growing only about 30 feet high, with a diameter from 15 to 18 inches.

(11.) *Jenisero.*—One of the most useful trees and one of the largest in the country. Attains a height of 90 feet, with 7 in diameter, and its largest branches cover a space of over 100 feet in diameter. In Nagarote, a town in the Departmento de Leon, at the junction of one of its streets with the large road from the western departmentos, there is a Jenisero whose branches cover a circumference of 348 feet (about 9498 feet area); it is 90 feet high, and has a circumference of 21 feet at 4 feet from the ground, according to Senor F. Guerreo Baster.

The wood has a light to dark color and a peculiar grain; it is open and wide in the annual rings, but very compact between. It

is used for cart wheels, lasting for years without tires on clay soil. Used also by the carpenters in various ways. Its fruit is eaten by the cattle and is used to sour the milk. It is fairly well distributed over the country.

(12.) *Jicaro-Sacaguacal.*—Attains a height of 20 feet and a diameter from 10 to 12 inches. Common on marshy land. It is of a nearly white color, and very tough, used in saddlery and for boat-knees. Resists moisture, and is durable in salt water. The shells, its fruit, after being worked, are used by the natives for drinking vessels. They carve them very beautifully and artistically.

(13.) *Laurel.*—Dark color, light, strong and elastic wood and very easy of working. There are two varieties, male and female, as they are popularly called. Used mostly in frames for cots and for work where elasticity is required. The dark kind is preferable. Both have a spicy smell. The tree attains a height of 40 feet and a diameter from 8 to 12 inches, seldom over 8.

(14.) *Lligualtil.*—This is one of the trees having many peculiar natural properties. Its fruits have a rich fragrance and flavor, and when green give out a coloring substance. From its bark a bluish and sometimes a purple substance is obtained, and from its sap thirty per cent. sugar may be obtained; is one of the most elastic woods found in Nicaragua. It is used for drum hoops, canes, etc. The tree seldom attains a height of twenty feet, and about twelve inches in diameter.

(15.) *Madera-Negra.*—One of the most useful trees found in Nicaragua, not only on account of its durability, strength and excellency for fire wood, giving out intense heat; but also from its method of growth. It is about the only tree used to shade the chocolate trees. It has a rapid growth, and is early produced from the seed. Mostly used for railroad ties, posts for houses, fence posts, foundations, etc. Has a dark, yellowish color in the heart, is fine grained, heavy and tough. It grows with oblong cavities, wasting a good deal of the wood when being dressed. However, straight logs, 1 foot square and 30 feet long, can be obtained.

(16.) *Madrono.*—There are two kinds, white and dark. It has a fine grain, and is heavy. Its strength may be seen from the tests in torsion and by transverse stress. Its growth is irregular and branching.

(17.) *Mahogany.*—This is too well known to demand description. In Nicaragua it is fairly well distributed. The best and most valuable is exported to a considerable extent from the Mosquito territory, where it grows abundantly, and to its fullest size. It is also found along the Pacific coast in considerable quantities.

(18.) *Moran.*—Solid and fine-grained wood of a beautiful yellow color. After it has been turned it looks as if had been polished; planes very easily. It is exported in great quantities as a dye-wood. Is often used for columns. Attains a height of from 30 to 35 feet, and a diameter of from 12 to 18 inches.

(19.) *Nacascolo.*—The wood is extremely heavy, very fine grained, and of a handsome dark color. Its toughness is shown by the test in torsion. The fruit is known by the names of *Nacascolo* or *Dividi*, and used for dyeing purposes when dry. It is one of the largest of hard-wood trees. Its trunk, although irregular in growth, and seldom over 20 feet to the point where it branches, is 6 feet in diameter. It attains a height of 60 feet, and is found more abundantly on the Atlantic coast. Is an excellent wood for railroad ties.

(20.) *Nancite.*—Has a soft pink color, fine grain and works very easily. The tree is small, grows on arid hills, and seldom attains 30 feet height. Its bark is used for tanning, and its fruits are to the Nicaraguenses what cherries are to the North Americans.

(21.) *Nispero.*—It may be said that there are two kinds, wild and cultivated. Large fruit tree of a thick and handsome foliage. The trunk is straight and free from limbs. The tree attains a height of 60 feet and a diameter of 2 feet. It is abundant all through the country, in farms near the towns, and in the wild forests. Exclusively used for wharves, bridges and posts. Resists moisture equal to any of the hard woods, and is said to petrify in the water. The wood is of an exceedingly fine grain, has a beautiful red color, and is very easily worked. It behaved the best of any under compression, bulging out considerably before showing any sign of shearing or split.

(22.) *Oja-tostada.*—Has a very light pink color, is fine grained and light. It is one of the most elastic and tough woods tested, as may be seen from the tests by transverse stress and by compression. It is very good for light and strong constructions.

(23.) *Palo de Arco.*—The sample tested planed easily in parts, and in parts less readily, probably on account of being green. Is

hard, has a fine grain, and a light red color. It is used for construction where easy of access. It grows along the coast, and in the coast range of mountains, attaining a height of 30 feet and 15 inches in diameter.

(24.) *Piedra.* (Stone.)—Has a fine grain, is heavy and strong, of a yellowish color in the sap, and deep red in the heart. Turns very smoothly, and is one of the hardest and heaviest woods known and yet not difficult to turn or plane. The tree attains a height of 40 feet, and has a diameter of from 15 to 18 inches. It is imperishable. Used in many places for pillars and transverse beams of houses on farms distant from towns, where it is easy of access. Is abundant on the hills along the coast on the Pacific slope. There are two varieties. It is an excellent wood, not only for interior decoration or for heavy furniture, on account of its beautiful color and fineness of grain, but also for heavy construction, as for foundations for engines or heavy machinery.

(25.) *Pochote.*—Tree of enormous dimensions. The wood is similar to the cedar, but more soft. It is used, however, in housework for doors, walls, floors, shingles, etc.

(26.) *Quiebra-hacha* (axe-breaker). There are two kinds, red and black. The latter, which was tested in three ways, is a most wonderfully tough wood. It has a color and appearance like the black-walnut, and its grain is similar to that of the oak. It planes beautifully smooth, and has a pleasing appearance, on account of its dark streaks. The red kind, which grows very straight and spreads considerably, reaches a height of 50 feet, and from 12 to 15 inches diameter. The dark kind, which spreads still more, seldom attains a height of 40 feet. Their name, axe-breaker, indicates their toughness; for in cutting or felling them the axe is often broken. In cutting the samples received, two axes were nicked to the extent of one-half to three-fourths of an inch. The wood is durable and used for ties, poles, etc., and in posts for houses. One piece that had been for sixty-seven years in a clay soil was found still sound when sawed. The tree is common throughout the state.

(27.) *Quita-Calson.*—It acts as a purgative. The tree attains a height of 30 or 35 feet, branching at 15 or 20 feet from the trunk, and often has a diameter of 2 feet. It is abundant along the coast. It is used for boards where not exposed to the weather; it will not resist moisture.

(28.) *Roble.*—Light colored wood of a curly and beautiful grain. It is pink in color and used in house-building. The tree has exceedingly large leaves, 14 inches long and about 7 inches wide, is often 50 feet high, and from 12 to 15 inches diameter. Is abundant along the coast.

(29.) *Ron-ron.*—This is one of the largest of hard-wood trees growing on the shores of the rivers of the Departmento of Chontales, on the Atlantic slope. It reaches a height of 50 or 60 feet, and often a diameter of 3 feet. Dark, fine-grained wood, strong, heavy and durable. Is used in cabinet work, turns very easily, and is susceptible of polish. It becomes dark with age.

(30.) *Tempisque.*—This tree is of historical interest in Nicaragua, and is one of the largest found in the tropical forests. It attains a height of 75 feet or more. The trunk is irregular and seldom reaches 20 feet to the beginning of the largest branches. It has a diameter of 6 feet. The wood is fine-grained, hard and very excellent for desks and other articles of cabinet work. Like the mahogany, it turns dark in a few years, and is equally durable. The cattle eat its fruit.

(31.) *Tiguilote.*—Light wood, grows about 30 feet high, and over 12 inches in diameter; good wood for carriages. It is used for fence posts; it easily roots when set with care, thus making a permanent fence and a pretty grove.

(32.) *Zapotillo.*—Of a light mahogany color, has a fine grain, and is light. Attains a height of 40 feet and 1 foot in diameter. It is not very much used.

(33.) *Zopilote* (Buzzard).—Coarse, long-grained wood, but of compact layers when viewed in cross-section. It has a greenish color. Turns and planes fairly well. The wood is used only in neighborhoods where more useful woods are scarce. When unexposed or when well seasoned and protected with paint, it would probably be a valuble wood, as it ran above the average in torsion, was among the highest in compression, and stood well under transverse stress. It attains a height of about 40 feet and 1 foot in diameter.

The transverse stress tests were made in the transverse testing machine of the Messrs. Fairbanks, designed for Prof. Thurston. It consists of a Fairbanks' scale combination, with a pointer and beam at the end to secure perfect balance. The whole machine

rests upon a wooden frame; upon the platform rests a cast iron cross beam, and upon this slide the supports, which are set and secured by bolts at the required distance apart. The test piece is placed upon the mandrels, which rest on the supports set at the required distance. The loads are put in the scale, and equilibrium is established by the elastic resistance of the piece offered against the pressure transmitted through the screw and pressure block by means of the lever. The screw passes through a nut, and terminates in a sliding piece. The cast-iron columns serve as guides to the pressure-block. The whole is made stable by wrought-iron braces bolted to the wooden frame. The deflections of the piece are measured by the linear advance of the screw, by means of a graduated wheel. The pitch of the screw was found to be equal to 0.33297 inches, and the wheel was graduated into 333 equal divisions, thus reading to $\frac{1}{10000}$th of an inch, with an error of 0.0001 of an inch. The pointer clamped to the screw is placed over the starting division in each case, and after the wheel has been turned and equilibrium established, the reading is taken. This is a very convenient way of reading the deflections, giving the difference directly. The test pieces were planed by hand by an expert, Mr. Kerr, and afterwards measured by means of a micrometer screw reading to $\frac{1}{1000}$th of an inch.

With all the data required, we obtained the results in the same way as in compression tests, by plotting the curve to each test, with loads as ordinates and the deflections as abscisses. This gives the elastic limit more exactly than in any other way. It also shows at a glance the behavior, strength, elasticity, etc., of the material tested.

Details of Transverse Stress Tests.

(1.) *Carbon.*—28-inch supports. Green sample from the sap and with a few small knots on top. Like the other, it broke just after having brought the beam up by its elastic resistance, under 550 pounds, and deflected 1.011 inches. Remained unbroken.

(2.) (?)————.—25-inch supports. A very well seasoned piece, but slightly weakened by a knot where it first gave way. The first rupture occurred at 950 pounds on the weak part. The second under 1150 pounds with a long and several other small splinters on tension side. Total deflection 1.687 inches.

(3.) *Chaperno.*—24-inch. A very good sample as regards soundness and seasoning. Cross-grained. Broke under 3700 pounds, with a deflection of 0.496 inch. Broke gradually in small splinters from the bottom side upwards, and crushed slightly on top also.

(5.) *Cortez.*—24-inch. A large sample from near the heart. Excepting two knots on thickness and bottom sides respectively, and check on sap line on top, it was a fine sample. Its toughness is shown by its behavior under load. Reached the elastic limit at 2500 pounds, broke at 4300 pounds, with a deflection of 0.443 inch. Second rupture occurred under 4650, with a deflection of 1.3975 inch. By diminishing the loads it might have given more ruptures without breaking completely. Broke in several adhering splinters on tension side.

(7.) *Guachipilin.*—11-inch supports. Good sample. The first rupture occurred under 1800 pounds load with 0.462 inch deflection. After the first rupture it showed a good deal of elasticity in resisting the loads and gradually ruptured slightly under 2050 pounds. The reason we took this latter for the rupturing load is on account of the behavior after the first rupture, which latter was very light, and on account of a weak point. Both ruptures were very light splinters and the piece might have shown still more tenacity if the load had been diminished. But here, as in most cases, we were after first rupture only. Almost any kind of wood will behave in the same way if so treated, unless it is very brittle.

(8.) *Guapinol.*—24-inch supports. An inferior sample, knotty near the middle, checked on top, and with a few worm holes. Broke under 1600 pounds with a deflection of 0.699 inch and with a few splinters on tension side.

(9.) *Guayabo de Monte.*—24-inch supports. The test piece was planed from a green limb. It was checked and knotty on either side of middle line in tension side. The first rupture occurred on account of cross-grain, at 660 pounds, with a deflection of 0.477 inch. Ruptured with only one splinter across the bottom side.

(11.) *Jenisero*—24-inch. Broke at 1600 pounds, with a deflection of 0.426 inches. When under 1600 pounds load, brought the scale up when pulling the lever arm, but immediately afterwards broke suddenly in two splinters. It evidently is very brittle.

(18.) *Moran.*—15-inch supports. A very sound and beautiful

natural-colored piece of wood. Ruptured in light splinters under 2600 pounds. with a deflection of 0.432 inches. Remained unbroken and could have still shown tenacity in successive ruptures.

(20.) *Nancite.*—32-inch supports. A good sample. Broke square on tension side, in two pieces, and very suddenly, after having offered elastic resistance, to 2200 pounds, and deflected 1.0765 inches.

(23.) *Palo de Arco.*—24-inch. Straight-grained sample, with two knots on bottom side. Broke at 2000 pounds, with a deflection of 0.679 inches. Second rupture occurred under 1 100 pounds load, with a deflection of 1.116 inches. Ruptured with close splinters on tension or bottom side.

(26.) *Quiebra-hacha negro.*—25-inch supports. Excepting a light streak of sap wood on bottom side, where it first gave way, it was a very sound sample. Its first rupture occurred when under 2450 pounds, with a deflection of 1.693 inches. A second rupture occurred at 2550 pounds, with a sudden crash and with a deflection of 2.080 inches. It is worth observing that the second rupture occurred with a larger stress than in the first one. The very finely intermingled narrow and regular splinters across the bottom side very fairly exhibit the high tenacity, ductility, as I may be allowed to say, and the uniformity of strength, cohesion and grain of this peculiar wood. Its rupture could very well be taken as the standard rupture of tough woods.

(27.) *Quita-Calson.*—21-inch supports. Season-checked on top and knotty on either side of middle line on the thickness side. Broke just under 750 pounds, with 0.811 inches deflection.

(33.) *Zopilote.*—11-inch supports. With a knot near one support gave way by shearing at that place when under 2550 pounds. Stopped the test at this point and took this as the rupturing load.

	Wood.	Dist'nce between supports l	Depth. h	Breadth b	Stress. E. Limit P	Stress. Rupture P'	Deflection at E. Limit d	Deflection at Rupture d'
		in.	in.					
1	Carbon	28	1.235	1.470	300	650	0.392	1.011
2		25	1.225	1.215	500	1050	0.478	1.354
3	Chaperno	24	2.000	1.994	2800	3700	0.36	0.496
4	Chiquirin	24	1.772	1.779	1800	2400	0.420	0.611
5	Cortez	24	1.740	1.745	2500	4300	0.443	1.073
7	Guachipilin	12	1.237	1.237	1200	2050	0.277	0.761
8	Guapinol	24	1.498	1.498	900	1600	0.335	0.699
9	Guayabo de Monte	24	1.495	1.495	300	710	0.157	...
11	Jenisero	24	1.742	1 742	1000	1600	0.426	0.810
13	Laurel blanco	28	1.775	1.730	1400	2150	0.139	0.265
14	Lligualtil	30	1.218	1.218	300	750	0.552	3.284
18	Moran	15	1.627	1.620	1600	2600	0.237	0.432
20	Nancite	32	1.98	1.983	1200	2200	0.4385	1.076
22	Oja-tostada	24	1.239	1.239	400	850	0.352	1.656
23	Palo de Arco	24	1.459	1.492	1200	2000	0.382	0.679
26	Quiebra-hacha-negro	25	1.479	1.473	1200	2450	0 395	1.693
27	Quita-calson	21	1.224	1.225	400	750	0.322	0.811
28	Roble	30	1.772	1.768	1000	1600	0.615	1.217
30	Tempisque	24	0.995	0.978	300	700	0.459	1.605
32	Zapotillo	28	1.734	1.734	900	2100	0.318	1.139
33	Zopilote	11	1.225	1.233	1450	2550	0 202	0.462
34	Guacuco	30	1.48	1 480	500	1170	0.438	1.526
35	Escobillo	30	1.745	1.741	800	1850	0.216	0.826

	Wood.	Stress in Outermost Fibre per Square inch, at— E. Limit. $p = \frac{3}{2}\frac{Pl}{bh^2}$	Stress in Outermost Fibre per Square inch, at— Rupture. $p' = \frac{3}{2}\frac{Pl}{bh^2}$	Total Elastic Resilience. $N = \frac{Pd}{2}$	Modulus of Elasticity. $E = \frac{Pl^3}{48\,d\,I}$
		lbs.			
1	Carbon	5613	12162	58	1514400
2		10272	21571	119	1824400
3	Chaperno	12575	16617	504	1672500
4	Chiquirin	11600	15467	378	1496300
5	Cortez	17025	29294	553	2119800
7	Guachipilin	11411	19490	166	614550
8	Guapinol	12206	21699	150	1858400
9	Guayabo de Monte	3232	7649	23	1322000
11	Jenisero	6803	6803	213	879780
18	Moran	8385	13624	189	815100
20	Nancite	7409	13583	263	1456500
22	Oja-tostada	7571	16088	70	1665500
23	Palo de Arco	13602	22670	229	2342900
26	Quiebra-hacha-negro	13966	28514	237	2490200
27	Quita-calson	6865	12872	64	1280300
30	Tempisque	11154	26026	68	2344600
33	Zopilote	12479	22730	141	1017100

The compression tests were made on the Olsen machine of 14,000 pounds capacity. The machine consists of four columns bolted to a plain cast-iron bed, and supporting on top a plate, in the middle of which one end of the test piece, if for tension, or the rod which holds the measuring apparatus is held by means of steel wedges.

Through the four angles of this bed and through those of that below pass four screws. To these latter is secured a plate, which pulls or compresses the piece, as the case may be. The plate rests upon four knife edges, on three beams or levers, and their ends rest together upon a link hung from knife-edges on each side of another beam, which latter is linked to the end of the scale in the same way. The machine is very sensitive. The scale is divided into divisions of five pounds. The load is applied by means of a crank or a lever turning a central wheel geared to four others, one on each screw. A powerful leverage and a steady vertical motion of the plate is obtained. The deflections were measured by means of micrometer screws, using the electrical contact. I quote Prof. Thurston's full description of the instrument:

"The instrument consists essentially of two very accurately made micrometer screws, working snugly in nuts secured in a frame which is fastened to the head of the specimen by a screw clamp. It is so shaped that the micrometer screws run parallel to and equidistant from the neck of the specimen, on opposite sides. A similar frame is clamped to the lower head of the specimen, and from it project two insulated metallic points, each opposite one of the micrometer screws. Electric connection is made between the two insulated points and one pole of a voltaic cell, and also between the micrometer screws and the other pole. As soon as the micrometer screw is brought in contact with the opposite insulated point, a current is established, which fact is immediately revealed by the stroke of an electric bell placed in the circuit. The pitch of the screws is 0.02 of an inch, and their heads are divided into 200 equal parts; hence a rotary advance of one division on the screw head, produces a linear advance of one ten-thousandth (0.0001) of an inch.

"A vertical scale, divided into fiftieths of an inch, is fastened to the frame of the instrument, and set very close to each screw-head and parallel to the axis of the screw; this serves to mark the starting point of the former, and also to indicate the number of

revolutions made. By means of this double instrument, the extensions can be measured with great certainty and precision, and irregularities in the structure of the material, causing one side of the specimen to stretch more rapidly than the other, do not diminish the accuracy of the measurements, since half the sum of the extensions indicated by the two screws is always the true extension caused by the respective loads."

The size of test pieces advised for compression varies with different authorities, the limit of the ratio of the length to the diameter being five times the diameter. The compression test should crush the piece down, or shear it at 45°, but even with the ratio used—the length equal to twice the diameter, as given and used by Prof. Thurston—the piece showed a slight buckling in some cases.

We have obtained the results from each test by plotting a curve, taking the loads as ordinates and the deflections as abscissas. In this way we see the behavior of the piece at a glance, by the curve, and find the elastic limit very accurate. This latter was obtained by drawing a straight initial line when necessary, and taking it as the point where the curve leaves the line.

We have given not only the results derived from the most common formula used either directly or indirectly in designing, but also the original data of size of test piece, the actual loads, unit strains and the stresses, as they may be found convenient in some cases and for obtaining further information if desired. The formulæ from which the results were derived are set at the head of the tables.

Wood.	Original.		Final Length.	Stress.			Strain.		
	Length.	Diameter.		E. Lim.	Max.	Brkg.	E. Limit	Maxim.	Break'g
2 Cedar	1.656	0.844	1.6273	2100	2300	2300	0.0189	0.0289	0.0289
5 Cortez	1.625	0.828	1.5815	5500	8100	8100	0.0224	0.0435	0.0435
6 Granadillo-negro	1.552	0.729	1.4733	4000	6500	6070	0.0115	0.0307	0.0795
7 Guachipilin	1.583	0.732	1.5546	3000	5000	5000	0.0102	0.0289	0.0289
9 Guayabo de Monte.	2.235	1.125	2.1893	6000	8500	8500	0.0191	0.0460	0.0460
11 Jenisero	1.506	0.794	1.4632	3000	4000	4050	0.0179	0.0341	0.0432
14 Lligualtil	1.609	0.828	1.5157	4200	6325	6325	0.0178	0.0804	0.0936
15 Madera-negra	1.609	0.812	1.5416	5500	6700	6650	0.0326	0.0574	0.0677
16 Madrono	1 625	0.812	1.5638	4800	6600	6000	0.0156	0.0335	0.0612
21 Nispero	1.625	0.828	1.5760	3500	7000	7000	0.0142	0.0490	0.0490
22 Oja-tostada	1.218	1.0859	2.1573	5000	8000	7800	0.0130	0.0316	0.0613
26 Quiebra-hacha	1.625	0.8281	1.5776	5400	8600	8375	0.0225	0.0864	0.0474
27 Quita-calson	2.224	1.119	2.1743	5000	8000	7600	0.0130	0.0318	0.0495
29 Ron-ron	1.625	0.828	1.1823	4200	5900	5900	0.0165	0.0427	0.0427
31 Tiguilote	2.219	1.126	1.1941	3800	5000	5000	0.0164	0.0251	0.0251
36 Guanacaste	1.5969	0.817	1.5560	3000	3700	3700	0 0135	0.0409	0.0409

Wood.	Unit Stress.			Unit Strain Elastic Limit.	Modulus of Elasticity.	Modulus of Resilience.
	E. Limit. $p=\frac{P}{F}$	Maxim. $p'=\frac{P'}{F'}$	Breaking. $p''=\frac{P''}{F''}$	$e=\frac{\lambda}{L}$	$E=\frac{p}{e}$	$U=\frac{p\lambda}{2L}$
1 Carbon	5600	9800	9585	0.0069	804860	19
3 Chaperno	2100	11500	11500	0.0035	593540	3
8 Guapinol	7800	12000	12000	0.0074	1051600	28
10 Guiliguiste	6000	8800	8800	0.0067	882940	20
12 Jicaro-sacaguacal	4000	7800	7800	0.0096	414020	19
20 Nancite	6000	8000	8000	0.0072	824340	21
21 Nispero	5600	10275	10000	0.0077	723550	21
21 Nispero	7000	14000	14000	0.0087	801050	30
33 Zopilote	7200	10800	10500	0.0099	721370	35

Wood.	Unit Stress.			Unit Strain Elastic Limit.	Modulus of Elasticity.	Modulus of Resilience.
	E. Limit. $p=\frac{P}{F}$	Maxim. $p'=\frac{P'}{F'}$	Breaking. $p''=\frac{P''}{F''}$	$e=\frac{\lambda}{L}$	$E=\frac{p}{e}$	$U=\frac{p\lambda}{2L}$
2 Cedro	4200	4600	4600	0.0114	367190	18
5 Cortez	11000	16200	16200	0.0137	797990	75
6 Granadillo-negro	8000	13000	12140	0.0074	1080300	29
7 Guachipilin	6000	10000	10000	0.0064	931470	19
9 Guayabo de Monte	6000	8500	8500	0.0085	702180	25
11 Jenisero	6000	8000	8100	0.0118	504880	35
14 Lligualtil	8400	12700	12650	0.0110	759440	46
15 Madera-negra	11000	13400	13300	0.0202	543010	111
16 Madrono	9600	13200	12000	0.0096	1000000	46
21 Nispero	7000	14000	14000	0.0087	801050	30
22 Oja-tostada	5000	8000	7800	0.0058	853320	14
26 Quiebra-hacha	10800	17200	16740	0.013846	780000	74
27 Quita-calson	5000	8000	7600	0.0058	855310	14
29 Ron-ron	8400	11800	11800	0.0101	827270	42
31 Tiguilote	3800	10000	10000	0.0073	514210	14
36 Guanacaste	6000	7400	7400	0.0084	709730	25

Wood.	Original.		Final Length.	Stress.			Strain E. Limit.
	Length. L	Diameter D	L	E. Limit. P	Maxim. P'	Breaking. P''	λ
1 Carbon	2.2421	1.128	2.1562	5600	9800	9585	0.0156
3 Chaperno	2.2611	1.1245	2.2096	2100	11500	11500	0.0080
8 Guapinol	2.2516	1.3115	2.2036	7800	12000	12000	0.0167
10 Guiliguiste	2.2515	1.128	2.2012	6000	8800	8800	0.0153
12 Jicaro-sacaguacal	1.625	0.8437	1.5534	2000	3900	3900	0.0157
20 Nancite	2.2532	1.1292	2.2238	6000	8000	8000	0.0164
21 Nispero	2.2611	1.1235	1.9522	5600	10275	10000	0.0175
21 Nispero	1.625	0.8281	1.5760	3500	7000	7000	0.0142
33 Zopilote	2.2704	1.126	2.2143	7200	10800	10500	0.0180

The torsion tests were made in the autographic testing machine of Prof. Thurston: It consists of two angle frames united at their vertices by a cast-iron rod and rigidly bolted to a heavy cast-iron bed, thus making the machine very firm. These two angles have the bearings in line with the jaws or wrenches which hold the piece to be tested by means of steel wedges put from opposite sides. The test piece is put in line before securing it rigidly between the jaws, by means of centres in each jaw, one resting on a spiral spring and the other turned by a screw which projects out of the frame, thus enabling to place the piece symmetrical and directly in line with the axis of rotation.

The outer end of one of the jaws is connected to a worm-wheel, the rotation to which is imparted through the worm by means of the crank. The other jaw carries the pendulum, to which is connected, a little below the jaw, the pencil, held by a spring tight against the sides of the guide curve. This curve is made so that when the pencil rolls on it, in virtue of the swinging of the pendulum with the test piece, the ordinates which are recorded upon a cross-section paper carried by a drum on the opposite jaw, or on the one connected to the worm-wheel, are proportional to the moments about the axis of the test piece. The machine, by the tracing of a simple curve, tells all the characteristics of the test piece. The circumference of the drum is equal to thirty-six inches, and the inches in the paper are divided into ten equal parts, thus making each inch of paper equal to 10°. The vertical lines are also divided into inches and each into tenths.

When the piece is secured between the clamps, the crank is turned by hand with a uniform motion, and a slow rotation, interrupted only by the rupturing of the piece, is given to it, causing the pendulum to swing up on one side. This measures the resistance to torsion of the test-piece, which is recorded autographically in the paper. The curve is the *locus* of the successive moments and of the corresponding angles as traced by the pencil.

To make these tests, we took off the bob from the pendulum, as it offers too large a moment for the torsional resistance of the woods for the size of test piece used. Before making the tests, we found the necessary constants of the machine to work out the results of tests, as follows: The pendulum without the bob was supported horizontally by a column, which rested on a scale.

Thus, the maximum moment of the pendulum was weighed, and the corresponding ordinate in the curve observed:

Lever arm, ...	48 inches.
Weight of column with lever arm, ...	52.75 pounds.
" supporting columns, ...	21.5 "
" lever arm, or pendulum, ...	31.25 "
Hence maximum moment, ...	1,500 inch-pounds.

Maximum ordinate traced by the pencil, or ordinate corresponding to horizontal position of the pendulum — 4.3 inches. Therefore, one inch of ordinate = 348.837 inch-pounds.

We found the friction of the machine by means of a delicate spring balance, attached at a distance of fifty inches from the center of suspension. The pendulum was pulled just far enough to overcome friction alone. After several trials, it was found to be equal to 0.25 pounds. This is probably a very accurate result. Thus, the friction of the machine is 12.5 inch-pounds, which friction is added, in every case, to the moments recorded by the pencil.

We took the size and form of test piece, as given by Prof. Thurston, and as adopted in the mechanical laboratory of the college.

The absolute errors in the size of the test pieces vary by excess from above one-thousandth ($\frac{1}{1000}$) of an inch up to a little above one-hundredth ($\frac{1}{100}$) of an inch.

We have put down the moments at the elastic limit, and at the maximum before rupture; also the angles of torsion at the elastic limit, maximum before rupture, and final rupture with the corresponding elongations of the outermost fibres for the first three angles. As a matter of detail, we have observed those which reached the final rupture with a higher moment after the first rupture, and those that did not offer a higher resistance. The names used express the character of the four critical points to which a material is subjected under an increasing stress.

Not being able to put in the strain diagram, we have endeavored to write out for illustration, the behavior of several pieces under stress, and their mode of rupture as concisely as possible, in the details of torsion tests. These may be more valuable than the numerical results. The torsion tests give a better and more general idea of all the properties of strength and elasticity of the

woods than any other test, as, in this case, they are compelled to write for themselves their "own story."

Details of Torsion Tests.

(1.) *Carbon.* $d = 0.6271$.—Test piece turned from a large sample near the heart. Very sound in the turned part. Elastic limit, maximum and rupture occurred under the same moment. From this and by breaking in two splinters it shows it is a brittle wood. It reached a moment at the latter points of 200.87 inch-pounds, at an angle of 7.5°, and gave away completely at 13.2° with no higher moment. Its curve was at 45° from the axis of angles and was short-wavy all along.

(2.) (?)————————————.—With a short wavy and parabolic curve reached its elastic limit at 7.11° under a moment of 186 inch-pounds, and reached a maximum of 190 inch-pounds moment, which kept constant for about 8°, when it came down and ruptured. Fairly regular stiff rupture.

(3.) *Chaperno.* $d = 0.6278$.—Turned from a large sample and very sound piece. It rose with a 45° wavy curve up to 104.9 inch-pounds when it reached the elastic limit. Went up to a maximum of 124.128 inch-pounds, which kept constant until final rupture, splintered at 17.3.°

(5.) *Cortez.* $d = 0.6278$.—Turned from a large sample near the heart. Very sound piece. It rose with a 45° curve and slightly wavy but uniform, reaching the elastic limit at 214.82 inch-pounds at an angle of 5.9.° Ruptured at 28° and splintered at 41°, reaching afterwards a higher moment, which kept constant till final rupture. Fibrous and stiff rupture, shearing a plug of same cross section as the turned part from the shoulder.

(8.) *Guapinol.* $d = 0.5645$.—With a slightly parabolic curve at 45° angle, reached its elastic limit at 6° with a 183 inch-pounds moment, which kept constant until first rupture and reached a little higher moment before final rupture. Gave away with wide fibrous splinters.

(12.) *Jicaro-Sacaguacal.*—The test piece was turned from a green limb. It rose with a parabolic line and very much inclined toward the axis of strains, reaching at the elastic limit a moment of 103.2 inch-pounds. Reached a higher moment, which kept constant

until final rupture at 155°, when it completely broke, irregular and stiff.

(13.) *Laurel.* $d = 0.631$.—Dark color. With a low sloping curve, but uniform, reached the elastic limit at 4° angle and under a moment of 82.268 inch-pounds. This was its maximum resistance, and kept constant until ruptured at 20°. Uniform square rupture around the shoulders without projecting splinters. Gave way entirely at 105° angle.

(17.) *Mahogany.* $d = 0.6358$.—A very sound piece, turned from a large sample. It rose with a long wavy line up to 78.779 inch-pounds, its elastic limit at 3° angle. Reached a higher moment of 82. inch-pounds at 6.7°, when it ruptured. It splintered at a still little larger moment at 27.6.° Fibres wide and stiff, and rupture irregular.

(18.) *Moran.* $d = 0.6256$.—A very sound piece. With a curve above 45° angle with the axis of strains reached its elastic limit at 2° under a moment of 82.27 inch-pounds, which kept constant for 1.5, when it rose to 88.95 inch-pounds moment, and gave away for the first time. However, it still reached about twice as large a moment, which kept constant till final rupture. Fibrous and tough rupture.

(24.) *Piedra* (Stone). $d = 0.6257$.—A piece turned from near the heart and very sound. It rose with a parabolic short wavy line up to the elastic limit, when it had a moment of 227 inch-pounds at an angle of 9.7.° It reached a maximum moment of 228.7 inch-pounds at an angle of 11°, and very soon lowered its moment to 221.8 inch-pounds, which kept constant until it splintered at 50°. Wide splinters and stiff rupture, but square around the shoulders.

(26.) *Quiebra-hacha.* $d = 0.6268$.—A very sound piece. It rose with a parabolic curve above 45° with the axis of strain, up to 166 inch-pounds moment, its elastic limit, and kept reaching higher and higher moments by regular intervals up to a maximum after first rupture of 319.479 inch-pounds, without giving way completely. Brushy, regular break, and very tough.

(29.) *Ron-ron.*—Dry and sound piece. Rose with a straight line up to 82.26 inch-pounds moment at an angle of 1.5°, and kept a constant moment till final rupture. Broke with brittle fracture in two pieces, without showing any fibre.

(32.) *Zapotillo.*—The test-piece turned from a large sample,

$d = 0.6258$ inch; had a small knot on one end, but very sound otherwise. It reached its maximum at the elastic limit, at an angle of 5.5° from the origin, rupturing with the same moment at an angle of 9°. It kept a constant moment for about 80°, when it reached a little higher moment, holding it till final rupture. Fibrous rupture.

(33.) *Zopilote.*—At first rose with a straight line below 45°, and turned parabolic near and after the elastic limit. First ruptured at 28° angle under a 106 inch-pounds moment, and raised it slightly, keeping the latter constant for over 160. A very thready and tough rupture.

Wood.	Moments of Torsion in in.-lbs.		Angle of Torsion in Degrees.			Maximum Shearing Stress.	
	E. Limit	Max. before Rupt.	E Lim.	Max. before Rupt.	First Rupt.	Elastic Limit.	Maximum before Rupture.
	$(P_a)_E$	$(P_a)_M$	α	α_1	α_2	$p^s = \frac{2}{\pi r^3} \times (P_a)_E$	$p = \frac{2}{\pi r^3}(P_a)_M$
2 Cedar.....	43.89	45.63	3.6	8.4	8.4	915	952
5 Cortez.....	68.3	71.80	3.3	19.	27.5	1424	1497
7 Guachipilin	82.268	148.54	2.6	49.	49.	1716	3098
9 Guayabo de Monte....	54.36	64.82	4.5	5.5	26.5	1133	1352
13 Laurel-macho....	68.31	71.8	2.8	4.1	4.1	1424	1497
15 Madera-negra.....	141.57	141.57	3.6	13.4	17.4	2953	2953
16 Madrono ...	99.71	103.19	4 5	29.	35.0	2080	2152
19 Nacascolo..	145.06	145.06	2.4	2.4	16.1	3026	3026
20 Nancite.....	61.34	68.3	2.7	12.	12.	1279	1424
21 Nispero.....	103.89	193.89	7.2	5.	9.5	4044	4044
22 Oja-tostada	52.616	54.36	2.7	14.5	19.5	1097	1133
25 Pochote.....	47.38	50.87	5.0	5.8	5.8	988	1061
26 Quiebra-hacha (yellow).....	152.03	152.03	5.0	5.	9.3	3171	3171
28 Roble.....	54.36	54.36	3.3	3.3	12.	1133	1133
31 Tiguilote ...	33.43	43.87	5.4	17 5	17.5	697	915
36 Guanacaste	68.31	71.8	2.25	3.2	3.2	1424	1497

	Wood.	Moments of Torsions in in.-lbs.		Angle of Torsion in Degrees.			Maximum Shearing Stress.	
		E. Limit $(P_s)_E$	Max. before Rupt. $(P_s)_M$	E. Lim. a	Max. before Rupt. a_1	First Rupt. a_2	Elastic Limit. $P^s = \frac{2}{\pi r^3}(P_s)_E$	Maximum before Rupture. $p_s = \frac{2}{\pi r^3}(P_s)_M$
1	Carbon.....	200.8	200.8	7.5	7.5	7.5	4190	4190
2	?	186.92	190.4	7.11	8.5	8.5	3899	3972
3	Chaperno...	104.9	124.1	3.4	5.7	7.3	2189	2589
5	Cortez.....	214.8	214 8	5.9	5.9	28.0	4481	4481
7	Mahogany..	78.7	82.2	3 0	6.7	6.7	1643	1716
8	Guapinol ...	183.4	183.4	6.0	18.2	18.2	3826	3826
12	Jicaro-sacaguacal....	103.2	110.1	20.	22.0	22.0	2153	2298
13	Laurel,dark	82.2	82 2	4.0	4.0	20.0	1716	1716
18	Moran.....	82.2	88.9	2 0	4.2	4.2	1716	1855
24	Piedra.....	227.0	228.7	9.7	11.0	11.	4736	4772
26	Quiebra-hacha.....	166.	166.0	8.0	8.0	8.0	3463	3463
29	Ron-ron	82.2	82.2	1.5	23.5	23.5	1716	1716
32	Zapotillo ...	99.7	99.7	5.5	5.5	9.0	2080	2080
33	Zopilote.....	94.4	106.6	5.7	28.0	28.0	1971	2225

	Wood.	Extension of Outer Fibre.			Modulus of Elasticity. $E_s = \frac{(P_s)_E}{a} \times \frac{l}{I_p}$	Total Elastic Resistance. $\frac{(P_s)_E \times a}{2}$
		E. Limit. $\lambda = \sqrt{1 + a^2(0.000029747)} - 1$	Max before Rupture.	First Rupture.		
2	Cedar	.....	.....	.....	46635	1
5	Cortez.....	.....	.....	.....	79161	2
7	Guachipilin....	.....	.....	.....	152358	2
9	Guayabo de Monte.....	.....	.....	.....	46203	2
13	Laurel-macho.	.....	.....	.....	93310	1
15	Madera-negra.	.....	.....	.....	150407	4
16	Madrono.....	.....	.....	.....	84748	4
19	Nacascolo	.....	.....	.....	231175	3
20	Nancite.....	.....	.....	.....	86893	1
21	Nispero.....	.....	.....	.....	102997	12
22	Oja-tostada....	.....	.....	.....	74533	1
25	Pochote	.....	.....	.....	36243	2
26	Quiebra-hacha (yellow).....	.....	.....	.....	116297	6
28	Roble.....	.....	.....	.....	63003	1
31	Tiguilote	.....	.....	.....	23678	1
36	Guanacaste....	.....	.....	.....	116119	1

Wood.	Extension of Outer Fibre.			Modulus of Elasticity.	Total Elastic Resistance.
	E. Limit.	Max before Rupture.	First Rupture.	$E_s = \frac{(P_s)_E}{a} \times \frac{l}{I_p}$	$s = \frac{(P_s)_E \times a}{z}$
	$\lambda = \sqrt{1 + a^2(0.000029747)} - 1$				
1 Carbon.....	.....	.....	.....	102440	13
2 ?	.....	.....	.....	100551	11
3 Chaperno.....	.....	.....	.....	118050	3
5 Cortez.....	.....	.....	.....	139270	11
8 Guapinol.....	.....	.....	.....	116920	9
12 Jicaro-sacaguacal.....	.....	.....	.....	19735	18
13 Laurel (dark)..	.....	.....	.....	78663	2
17 Mahogany	.....	.....	.....	100440	2
18 Moran.....	.....	.....	.....	157330	1
24 Piedra	.....	.....	.....	89522	19
26 Quiebra-hacha	.....	.....	.....	79363	11
29 Ron-ron.....	.....	....	.....	209750	1
32 Zapotillo.....	.....	.....	.....	69339	04
33 Zopilote	.....	.....	.....	63390	4

ON RECENT FIELD WORK IN THE ARCHÆAN AREAS OF NORTHERN NEW JERSEY AND SOUTHEASTERN NEW YORK.*

BY N. L. BRITTON.

In the spring of 1885 I was commissioned by Professor George H. Cook, State Geologist of New Jersey, to undertake the study of the Archæan rocks of that State, with a view to ascertain if it were possible to divide them into any convenient groups; and also to note their relations to the Palæozoic strata. I was further instructed to examine the crystalline rocks of southeastern New York, of which the New Jersey areas are but the southwestern continuation, as it appeared probable that data could there be obtained which were not obtainable in New Jersey. While the survey of the region is by no means completed, some results have been reached and hypotheses suggested which may be worthy of brief consideration.

The Archæan rocks of the territory under examination may be conveniently regarded as of two areas. The one consists of the

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Highlands of Putnam, Dutchess and Orange counties, New York, and of Bergen, Sussex, Warren, Morris and Hunterdon counties, New Jersey, continued to the southwest in the South Mountain, Chestnut Hill, etc., in Pennsylvania; the other, of the greater part of Westchester and New York counties and portions of Queens and Richmond counties, New York, a few outcrops at Jersey City and Hoboken, and again at Trenton, New Jersey, continued to the southwest in the rocks which underlie the city of Philadelphia. I speak of these as two areas, and, geographically, they are separated from the Delaware River to the northern line of Westchester County. At the Delaware the Triassic strata spread for thirty miles between the two, but proceeding northeast the areas rapidly approach until at Annsville Cove, New York, they are separated by but a narrow valley of Palæozoic limestone, quartzite and slate.

These Palæozoic rocks have locally been greatly altered, and in some places rendered even crystalline, by the intrusion of molten material, forming the peridotites, quartz porphyries, etc., of Stony Point, Cruger's, Verplanck's Point and elsewhere. The intense metamorphism which they have undergone is very instructive, and furnishes the most conclusive proof of local alteration of rock masses of considerable extent. Indeed, the alteration has been so great that it is only by the closest observation that some of these rocks can be distinguished in the field from those of the upper Archæan.

Turning now to the first of the areas before mentioned,—the Highland Archæan,—we find that its rocks have very generally been regarded as of Archæan age; indeed, I know of no published opinion to the contrary. The rocks are all strongly crystalline, and, as a whole, agree well with those of the classical Laurentian of Canada. There can be but little doubt that the rocks of the two regions were practically synchronous in deposition, and if we omit the norite of Canada (and if this rock is of igneous origin, as has been strongly urged, we may fairly do so), the two are practically identical. On the other hand, the Huronian has not been recognized.

In the study of this "Highland Archæan" it was found, after comparing a vast number of sections, systematic field observations, and lithological specimens, that there was a *base* to the series, of nearly constant character and mineral composition. It is a very dense crystalline aggregate of orthoclase and oligoclase, glassy

quartz and hornblende. Ordinarily there is little or no mica in this basal rock, but locally, and notably in the Pochuck Mountain, biotite is present in appreciable amount. Hornblende varies considerably in quantity, sometimes making nearly half the rock; in other cases entirely absent. Quartz is present in greater or less abundance in all the thin sections yet examined, and is generally apparent to the unaided eye. The rock is massive, very indistinctly bedded, the layers of stratification being marked in most instances by mere parallel arrangement of the crystals, though locally bedding planes have been noticed and measured. I have written of these rocks in recent reports of the New Jersey Survey as quartz syenite, granulite and granite. The variety designated quartz syenite would, under the classification of Rosenbusch, pass as amphibole granite and granitite. The areas underlain by them are very irregular in outline, and some of these are laid down on maps published in the New Jersey Report for 1886; the irregularity of the areas is caused by the folding of the strata, the northeast *pitch* of the folds, and the very great amount of erosion of the surface; they also vary greatly in size, some occupying only a few hundred square feet, others several square miles. Their occurrence was first made known by Mr. J. C. Smock, in 1884. These massive rocks have been quarried to a limited extent, but furnish good, strong building-stone. Magnetite occurs in them only in specks, not very noticeable in the field, but apparent in thin sections; no workable masses of iron-ore have been discovered. Indeed, the mineral composition of this "MASSIVE GROUP," as I have provisionally designated it, is simple, as compared with the overlying strata, and includes none of the elements generally cited as indicative of the existence of life in Archæan time.

The beds which rest on these basal rocks are distinguished by their very evident stratification, their more complex mineral composition and by the abundance of magnetite, this often forming entire strata, which reach a thickness of thirty feet or more, and furnish all the half million tons of magnetic iron ore annually mined in New Jersey and southern New York. From this character I have called these rocks the "IRON-BEARING GROUP." Here also occur most of the crystalline limestones of the Highland Archæan, their horizon being very near that of the magnetite beds, probably a little above them in most cases. These limestones are very coarsely crystalline, contain scattered flakes of graphite, much

chondrodite and a great variety of less abundant minerals, and are of the highest degree of interest as the enclosing rock of the Franklin Furnace and Stirling Hill manganese-iron-zinc deposits. These are beds bent into synclinal folds, the axial planes of which tilt to the southeast, their axes pitching to the northeast. The ordinary country rock of the Iron-Bearing Group is granulite, more or less hornblendic, varying, when the amount of hornblende is great, to a quartz syenite, and, when the mica is abundant, to heavily-bedded biotite gneiss in the upper strata of the group. We have also beds rich in hornblende and pyroxene, with triclinic feldspars, which have not as yet been thoroughly studied, but in some cases have the mineral composition of diorite and diabase. It may be remarked that this group contains the cited evidences of organic existence in Archæan time—limestone, iron-ore, apatite and some graphite, and some of the ophiolites greatly resemble the rock which contains the dubious organism, *Eozoon Canadense.*

The upper part of the Highland Archæan series consists of much more schistose strata, being made up mainly of biotite gneiss and schist, hornblende schist, chloritic schist, talc schist, tremolite and kyanite schist. Locally there are also fine-grained granulites, red hematite similar to that of Rossie, New York, "bedded diorite," graphite and graphitic schist in workable beds, and magnesian crystalline limestone. Another noteworthy character of this group is the great abundance of segregated masses of coarse granite and pegmatite. Segregation is much more pronounced at this horizon than in the lower groups. At present we see no practicable method of subdividing this "GNEISSIC AND SCHISTOSE GROUP," though farther field study may render this possible.

The three groups into which I have provisionally divided the Highland Archæan may be conveniently represented in tabular form:

ARCHÆAN SERIES—LAURENTIAN SYSTEM.

III. GNEISSIC AND SCHISTOSE GROUP.	Biotite gneiss and schist; hornblende, talc, kyanite and tremolite schists; graphite and graphitic schists; "bedded diorite;" red hematite; magnesian crystalline limestone; segregated masses of coarse granite and pegmatite.

II. IRON-BEARING GROUP.	Stratified granulites, hornblendic granulites and heavily-bedded gneisses; beds of magnetite and accompanying minerals; crystalline limestone, dolomite and ophiolite; Franklinite and its accompanying minerals; "bedded diorite and diabase."
I. MASSIVE GROUP.	Quartz syenite, granulite and granite with little or no bedding.

These three groups are not sharply separable; indeed, there can generally be traced a gradual passage from one into another, and no unconformability has anywhere been detected. The sequence is by no means always complete, however, for the iron-bearing group is wanting in many sections, the upper group resting directly on the massive.

Turning now to the second great Archæan area, we find that in New Jersey it is only well exposed for study in the vicinity of Trenton, where it underlies three or four square miles and separates the Triassic red rocks on the west from the Cretaceous clays, sands and gravels on the east. As shown in the few outcrops the lithology is here essentially that of parts of the gneissic and schistose group of the Highlands, there being biotite gneiss and schist, "bedded diorite" and abundant segregated masses of coarse granite.

Northeast from Trenton there are no known exposures for a distance of over forty miles, until Staten Island is reached, where the Archæan is represented by a single granite outcrop, several of tremolite schist, and a great development of serpentine and talc schist. But between Trenton and Staten Island there is sufficient evidence of the occurrence of crystalline rocks at a moderate depth. They were encountered in a well bored at Perth Amboy, and the abundance of feldspar, mica and quartz beds in the base of the Cretaceous system shows that the crystalline rocks are not far away. The outcrops of gneiss and serpentine at Jersey City and Hoboken are too limited in extent and too much obscured by buildings to yield satisfactory observations.

Coming to New York Island and Westchester County, we reach the ground rendered famous by the investigations of Professor J. D. Dana in 1880 and 1881, when he supported the view that the rocks are of Lower Silurian age. These are mainly mica schists, biotite gneiss, hornblende schist, granulite, dolomite,

and much segregated granite. Lithologically, they agree in great part with the gneissic and schistose group of the Highland Archæan, there being areas, however, which are more schistose than any of equal size in New Jersey, and the Westchester County rocks include far more dolomite than is found in the upper Highland group. These are differences of degree rather than kind, although the extremely micaceous beds of Westchester County, which lie in synclinal folds, may be still slightly higher in the series than anything yet encountered in New Jersey. There are doubtless some basins of more or less altered Palæozoic rocks in the northern part of the county, but by far the greater portion of the rocks are unquestionably Upper Archæan.

Considering now very briefly the observed phenomena of contacts between the Archæan and Palæozoic rocks, we find that all along the northwestern border of the Highlands there appears to be decided unconformability. But the basal quartzite or sandstone is so heavily charged with feldspathic material that it is only in new, clean excavations that the exact line of junction can be located to within several feet. Along the edges of Palæozoic basins enclosed by the Archæan hills the unconformability is not as marked, while along the southeastern margin of the area there is little or no difference in the position of the beds, the basal quartzite of the Palæozoic series, very heavily feldspathic, and appearing to grade directly into the older rock, suggesting the possibility of passage beds. I will cite a single one of these interesting cases.

About a mile and a quarter northwest of Whitehall station on the Boonton Branch of the D. L. & W. R.R. is a hill, of which the eastern base marks the western border of the Triassic sandstone. A few feet above its base are abundant outcrops of a gray silicious slate, traversed by thin quartz veins, and having a strongly-marked slaty cleavage across its bedding which has strike N. 70° E., dip 75° S.E. This would seem to be Palæozoic without question. Proceeding up the hill the rock becomes more and more feldspathic and contains increasing quantities of biotite, and ultimately a true biotite gneiss is encountered at the summit, the whole succession of beds being strictly conformable, and resting conformably on the ordinary hornblendic granulites of the iron-bearing group. This condition of things was traced nearly continuously for over half a mile northeast and southwest. Possibly

the alteration may have been caused by the intrusion of igneous rock, as it has been around the Courtlandt series before mentioned, but none was certainly observed at this locality, though small amounts of greatly decayed material, which may possibly have been diabase, were noticed. These phenomena are suggestive, but they certainly are not to be explained as indicating the Lower Silurian age of the Highlands, and yet it was mainly on such evidence that the theory of the Lower Silurian age of Westchester County and New York Island was constructed!

In conclusion, I should state that the succession of strata now made out in the Highland Archæan was determined quite independently of any published accounts of the stratigraphy of other regions. Indeed, in attempting to digest the information on record in the vast literature of the subject, it was early determined, in view of the many contradictory opinions expressed, to start anew and endeavor to reach some independent conclusions regarding our own territory. Now that this has been done it appears probable that there is a very similar sequence in the Laurentian of Canada, judging from the published papers of Dr. T. Sterry Hunt. The "Ottawa," or "Fundamental Gneiss," agrees closely in description, with my "Massive Group." The "Grenville series" appears practically identical with my "Iron-Bearing Group," and my IIId Group has many features in common with Dr. Hunt's "Montalban System."

I have not made a critical study of other regions to ascertain if the sequence obtains elsewhere. A few observations made at different times in the Adirondacks, indicate that the two upper groups at least are there represented, and I have also recognized these in the Blue Ridge. If the sequence proves generally what I have found it in the Highlands, and if the succession of the Canadian rocks is the same, of course Dr. Hunt's names for the groups have priority over mine, and must ultimately be adopted.

I take pleasure in expressing my obligation to Professors Cook and Newberry for advice and counsel in the prosecution of this investigation; to Mr. F. J. H. Merrill, who accompanied me in the field during the first season, and has since aided me in various ways, and to Mr. James F. Kemp, to whom I am indebted for numerous petrographical examinations.

INVENTION AND SKILL.

BY FRANCIS H. RICHARDS.

THE judicial definition of Invention, as distinguished from Mechanical Skill, seems not only inadequate, but, to some extent, erroneous. Authority concedes genius to the inventor, while only crediting the mechanic with the work of his hands. But from the mind spring the works of both inventor and mechanic; and while their works are different, these are not to be distinguished by the absence or presence of thought.

In a recent case, a Circuit Judge said: "Invention requires thought, mechanical skill does not. The one is the result of mental, the other of manual action." Though terse, this is ambiguous. For what is invention, and, much more, what is "thought"? Surely it must be admitted that even the exercise of skill involves "the act of thinking," so that the "thought" said to be required for invention must be *thinking* under some limitation. Sometimes, as by Webster, thought is defined as "the exercise of the mind in any way except sense and perception." This is probably the meaning adopted in the quotation. But even when thus limited, the definition is inadequate, and most clearly so if in the term "mechanical skill," we include the skill of the artisan,—or any skill above that of the laborer.

It is easy for those living in the world of words, for the judge on the bench and the scholar in his study, to imagine themselves using a higher order of thought, thought *per se;* to imagine the mechanic has, in the practice of his art, no use for those higher cognitive faculties—comparison and reason. But let the theorist familiarize himself with the handicrafts, and especially let him attempt to practice the art, for instance, of the machinist, and this illusion will quickly vanish. If they who have analyzed and set down in order the special faculties, and nicely discriminated the operations of the mind, and have given the modes and limits of thought *as* thought,—if these will study but for an hour the operations of a modern machinist, they will find exhibited not only sense and perception, but also imagination, the faculty of relations, and reason,—all the kinds of mental action employed by themselves, or by the inventor. Is it not by *thought* that the mechanic

plans and arranges the operations for finishing a forging? How, if not by *reason*, "mental *action*," reflection and judgment, does he arrange and time the steps of his processes so that each step shall be completed without interfering with the result of some other step? The truth is, his every step is carefully considered in the light of past experience; the conditions of that experience and those of the case in hand are observed and compared; and reason, judgment, decides in what and how far the old process shall be modified to suit the new circumstances.

The object, that about which the knowing subject is conversant, rather than the mode of thought, is to be considered in distinguishing invention from skill. It is doubtless true, as pointed out by the advocates of the *thought* theory of invention, that the object of invention when reached is perceived instantly; that the inventor does not, as a rule, consciously follow out step by step a course of reasoning leading thereto. But this phenomenon of instantaneous perception does not seem to be at all peculiar to the thinking involved in the exercise of invention; but to be common to the ordinary exercise of thought whatever may be its object. The mechanic no less than the inventor, seeking to know how to produce in a given case a particular result, brings thought to bear on the problem, and the object, when it is reached, stands instantly revealed to his mind. In all this, thought is very like sight. The eye looking through a glass unadjusted, sees but darkly; but as the lenses are brought to the proper focus, the objects in the field of vision spring into clear view. In similar manner the inventor or the mechanic studying a problem, sees at first but a chaos of possibilities, until finally the object of his thought flashes into the field of his mental vision. Then he sees no longer darkly, but face to face, yet all thoughtless of the mental processes involved in that illumination.

What, then, is the object, and what is the nature of Invention? Like skill, it is incorporeal, and invisible except through its embodiment; while both are mental faculties, the exercise of either of which involves thought. How, when comparing a new structure with an old one, shall we know whether the improvement is due to invention or to skill; whether it is the result of skilful thought or of inventive thought? A definite and correct solution of this problem is not only of interest, but of practical importance, since presence of invention is the first requisite to patentability.

Invention, as exercised in the mechanic arts, is *the making original discovery*, for and to one's self, *of a process.*

Process is defined to be chemical or mechanical procedure; certain steps or elementary operations taken or performed in a certain order of succession, and each contributing to one final result. Processes may be classified as simple, compound and complex. A simple process consists of two or more simple steps; a compound process, of two or more processes, one following the other, but each complete in itself; a complex process, of two or more steps of which one (or more than one, but less than all) is in itself a process. Necessarily, a process is unchangeable. If any step is omitted, or if substitution is made of one step for another, we have not a modified process, but a different one,—either new or old, as the case may be. But processes may, nevertheless, be modified, quantitively and qualitatively; one or more of the steps may be increased or diminished in time or force, in relation to other steps; this is the work of skill.

A process may exist in three forms, or *tenses*, accordingly as invention be exercised in making discovery of the process *per se* (present tense); of a product of the process (past tense); or of means whereby the process may be carried out (future tense). Whatever the form, the object of invention appears always to be the same,—namely: process; and hence newness of process is the test of invention.

Planning, merely, even though it be of a new structure, is not invention. For instance, a plan may be made of a new arrangement in a machine of an old combination, and yet the combination as such remain unchanged. This, merely, cannot be invention. And yet there may be involved in the production of such a plan, not only consummate skill, but also the highest order of thought. To this class belong very many of the modern improvements in machinery, which are none the less useful because not invented.

Contriving a means (machine or apparatus) for carrying out a process is not necessarily invention, nor the means contrived an invention. But in such contriving there may be made a combination which shall carry out by itself a new process (certain mechanical procedure) that is contributory to the object-process of the machine. This adjunct process is the object-process of such combination considered as a separate or sub invention.

Practically considered, invention is the making original dis-

covery for and to one's self of the subject-matter, or of means for carrying out, or of the product of, a process.

Invention is conversant about discovery of process; skill, about the practicing of processes. Invention is a pioneer who reaches out into the borders of the unknown, and marks out a new pathway to some point either before known, or by him made known. Skill, on the other hand, dwells with her servants, power and industry, within the limits of the explored country, nor steps aside from the beaten way; she multiplies over and again the things that were made, and rears the works of her hands throughout the widening realm of the conqueror, Invention.

THE BURLINGTON BRAKE TESTS.

BY H. HOLLERITH.

THE Master Car Builders' Association, evidently appreciating the importance of some action on their part with regard to the question of equipping freight trains with some efficient automatic power-brake, appointed a committee which conducted an elaborate series of freight-brake tests at Burlington, Iowa, in July, 1886. On this occasion there were two classes of brakes tested. The continuous brakes were represented by the Westinghouse automatic air-brake and the Eames automatic vacuum-brake. The independent brakes were represented by the American buffer-brake, the Rote buffer-brake, and the Widdefield and Button brake. As none of these brakes, in the opinion of the committee, did satisfactory work with trains of fifty cars, a new series of tests were conducted by the same committee at Burlington last May, with fifty-car trains. The introduction of some new devices for controlling the brakes so materially increased the efficiency of the brakes that an examination of the records of these tests, it is believed, must prove interesting.

At the tests last May no independent brakes were represented. Their inefficiency, however, had been practically demonstrated at the previous tests. The Hanscom automatic straight air-brake

and the Card electric-brake were withdrawn from the contest, leaving but three competitors—the Eames Vacuum-brake Co., the Westinghouse Air-brake Co., and the Carpenter Electro-Air-brake.

As both the Westinghouse and the Eames train were equipped with electrical attachments to operate their brakes in addition to their ordinary appliances, there were virtually five different brakes in competition.

These brakes were all continuous pneumatic brakes, and consisted essentially of the following elements: a brake-cylinder, or its equivalent diaphragm, on each car, with the necessary connections to the brake-shoes; a reservoir for storing power, either compressed air or vacuum, and a train-pipe provided with suitable connections or couplings from car to car. The power in all cases was provided by a pump, or its equivalent ejector, located on the engine. The brakes differed essentially only in the method and appliances for controlling the communication from the auxiliary reservoirs to the brake-cylinders and from the brake-cylinders to the atmosphere, thereby controlling the application and release of the brakes.

The following is a brief description of the essential features of the different brakes as tested at Burlington last May.

The Eames Automatic Vacuum-brake.

The engine for this brake was equipped with an ejector having two jets; the larger was used only for producing the vacuum throughout the train, the smaller one was used for maintaining the vacuum against leakage. The train was connected throughout by a two-inch main pipe. Each car was equipped with two diaphragms, one for each truck, and an auxiliary reservoir. Communication between the auxiliary reservoir and the brake-diaphragms was controlled by the automatic valve (corresponding in its functions to the Westinghouse triple valve). This valve is operated by the difference of pressure in the train-pipe and the auxiliary reservoir, in such manner that as air is admitted to the train-pipe, communication is established between the brake-diaphragms and the auxiliary reservoir, thereby applying the brakes, the force with which the brakes were applied being proportional to the quantity of air admitted to the train-pipe.

The Eames Automatic Electric Vacuum-brake.

In addition to the above equipment the Eames train was provided with a small dynamo and engine on the locomotive, and attached to each automatic valve throughout the train an electro-magnet, which operated a valvular apparatus controlling the admission of air to a small chamber, back of a small diaphragm connected with and operating the main valves for applying and releasing the brakes. This chamber is ordinarily in communication with the train-pipe. The electro-magnets were connected throughout the train in series, and by means of a suitable switch under control of the engineer, could be thrown into circuit with the dynamo. The brake thus equipped could be applied in the ordinary manner by the admission of air to the train-pipe, or by the train breaking in two, thereby filling all the chambers back of the small valve diaphragms, and thus operating the main valves. These valves and diaphragms are so arranged that the degree of force with which the brakes are applied is proportional to the quantity of air admitted to this chamber. The electro-magnets are located in small chambers normally in communication with the external air. As the armature is attracted this opening is closed, while at the same time opening communication from this chamber to the small chamber back of the valve-diaphragm. This admits a certain amount of air to the latter chamber and applies the brakes partially, according to the relative size of the two chambers. To apply the brakes with more force the operation is repeated. To apply the brakes fully, as in making emergency stops, the circuit is made and broken several times in quick succession. In this manner a good control of the force with which the brakes are applied is obtained. While the circuit is closed through the electro-magnets, communication from the train-pipe to the chamber back of the valve-diaphragm is cut off, so that the vacuum in the train-pipe, auxiliary reservoirs and brake-diaphragms may be maintained or even augmented while the brakes are applied. This is an important consideration, especially in descending long grades. To release the brakes it is simply necessary to break the electric circuit, thus releasing the armatures of the electro-magnets and thereby establishing communication from the valve-diaphragm chamber to the train-pipe, producing a vacuum in this chamber and thereby operating the main valve to release the brakes.

The circuit was made throughout the train by a wire connected to the metallic hose-coupling at the ends of each car, the couplings themselves being thoroughly insulated by the rubber hose to which they were connected. The return circuit was effected through the rail by grounding at each end of the train.

The Westinghouse Automatic Air-brake.

The Westinghouse train was equipped with their well-known form of brake apparatus, except that the triple valve was of an improved construction. In the ordinary triple valve, as in use at the present day, the valvular apparatus controlling the application and release of the brakes is operated by a small piston, actuated in one direction by the pressure in the auxiliary reservoir, and in the other direction by the pressure in the train-pipe. The brakes are applied by reducing the pressure in the train-pipe, the force of application being proportional to the reduction of the train-pipe pressure—a reduction of about twenty pounds being sufficient usually to apply the brakes with full force. With the Westinghouse brake, as tried at Burlington in 1886, it was found that about seventeen seconds were required to reduce the train-pipe pressure sufficiently to apply the brakes at the end of a fifty-car train. This was with the same form of triple valve as is now used on almost all the passenger equipment in this country. To expedite the action of the triple valve, Mr. Westinghouse has added to it another valve controlling communication from the train-pipe direct to the brake-cylinder. When only a slight reduction is made in the train-pipe pressure the action of the triple valve is the same as before. When, however, a quick or emergency stop is wanted, the train-pipe pressure is reduced sufficiently to bring the piston of the triple valve down far enough to operate this supplemental valve, which allows the air in the train-pipe to rush into the brake-cylinder until the pressure in the cylinder is equal to that in the train pipe, when communication is closed by an ordinary check-valve suitably located. At the same time that the supplemental valve is operated, communication is also established between the auxiliary reservoir and the brake-cylinder through the ordinary triple valve, thus securing the maximum application of the brakes. The first sharp reduction of the pressure in the train-pipe starts the triple valves on or near the engine, the remaining valves throughout the train being operated

successively by the reduction in the train-pipe pressure effected through the operation of these supplemental valves.

The Westinghouse train at Burlington, equipped with a one-inch pipe and these new quick-action triple valves, reduced the time required to operate the triple valve on the last car of a fifty-car train to about five or six seconds, showing a remarkable gain in rapidity of action over the ordinary triple valve as tested at the tests of 1886. On the other hand, the shock experienced in the rear car was so great that but three stops were made with a fifty-car train. This form of brake was virtually withdrawn from the tests on account of this shock in the rear cars.

The Westinghouse Automatic Electric Air-brake.

In addition to the ordinary Westinghouse equipment as described above, the train at Burlington was equipped with a small battery on the engine, and an electric switch connected with the engineer's valve in such manner that when the valve was brought to a position to apply the brakes quickly, as for an emergency stop, a circuit from the battery to a wire extending throughout the train was closed. The wire forming this circuit was carried inside the train pipe and air hose. The connection from car to car was made automatically when coupling the air-hose, by insulated, spring-actuated, metallic contact buttons located in the centre of the air-hose couplings. Several portable electric valves were used. These were so arranged that they could be carried anywhere between the ordinary air-hose coupling and a coupling piece secured to the end of the train pipe. When these valves were thus coupled in position the circuit would be made through the coils of an electro-magnet, the armature of which operated a valve controlling communication from the train pipe to the atmosphere. Several of these valves were carried in the train, as for example, one at the end of the twentieth and one at the end of the fortieth car. When now it is desired to make an emergency stop, the engineer's valve is brought to such a position that the circuit from the battery is closed through these electro-magnets, so that the train pipe is opened to the atmosphere through these portable valves at the same time with the engineer's valve, thereby quickly reducing the pressure throughout the train pipe and thus applying the brakes through the action of the triple valves. These electric

valves are not used in applying the brakes easily, or in graduating the brake, which is done as with the ordinary Westinghouse brake. To release the brakes the circuit is broken, and the train pipe is then charged from the main reservoir on the engine in the usual manner, the time required to release the brakes being thus largely dependent upon the length of the train.

THE CARPENTER ELECTRO-AIR BRAKE.

The equipment of this train was essentially the same as that of the Westinghouse train, except that the typical feature of the Westinghouse brake, the triple valve, was replaced by an electrical valvular apparatus. This consisted of a suitably arranged casing having two valves, one controlling the communication from the auxiliary reservoir to the brake cylinder, the other from the brake cylinder to the atmosphere. Each valve was operated by a suitable electro-magnet, controlling, by means of a small valve secured to its armature, the pressure in a small chamber above a diaphragm connected to the valve stem. Two circuits extended throughout the train. In one circuit were arranged the magnets controlling the inlet valves, and in the other circuit the magnets controlling the outlet valves. To apply the brakes it was only necessary to close the inlet circuit by means of the engineer's switch, which instantly and simultaneously operated all the inlet valves throughout the train, thereby applying the brakes. The brakes were released in similar manner by closing the outlet circuit. The application and release of the brakes could be perfectly controlled and graduated by the length of time the respective circuit was held closed. As the condition of the train pipe is not disturbed when applying the brakes, this being effected through the electrical devices as just explained, the auxiliary reservoirs can be replenished while the brakes are applied. In addition to the electrical control of the inlet valves, they were so connected with a small piston that they would operate, upon reduction of the train-pipe pressure, to apply the brakes, the automatic feature of the brake being thus fully provided. Furthermore, in case of accident or failure of the electrical apparatus, the brakes could thus be operated by reducing the train-pipe pressure as is ordinarily done to apply the Westinghouse brake.

As the electro-magnets had merely to operate very small valves

supplemental to the main valves as just explained, it will readily be seen that the amount of electricity required to operate the valves of even a fifty-car train is very small, and this is used only during the few seconds while operating the valves to either apply or release the brakes. The magnets were arranged in multiple arc, each magnet having a resistance of 200 ohms. The electromotive force was supplied by a "Julien" secondary battery of eight cells.

In accordance with the requirements of the committee, each brake company furnished an engine and fifty box cars of 40,000 pounds capacity, or over, equipped with its brake. The engines were the ordinary four-wheel connected with four-wheel truck, cylinders 17 by 24, and not less than 71,000 pounds on drivers. Each car and the tender were fitted with brakes on both trucks, with plain cast-iron shoes. Plain wrought-iron shoes were used on the drivers.

A dynamometer car was attached to the engine in each test, provided with apparatus for autographically recording the speed of the train and the tension or compression of the draw bar. An autographic recording apparatus for recording the speed, distance, and the brake-lever pressure, was placed in the middle car of each train. The rear car of each train was fitted with gauges for indicating the pressure in the auxiliary reservoir and in the brake cylinder. The slideometer for measuring the shocks during the stops was also placed in this car. It consisted of a 16-pound turned iron weight free to slide in a planed deal trough. The committee in their circular stated "a movement of more than 12 inches will be considered objectionable as indicating a shock violent enough to injure stock."

The tests were made on a section of the main line of the C. B. & Q. R.R., from Middletown to Burlington, a distance of about eight miles. Stops were made at four posts, Nos. 1 and 2 on a level, Nos. 3 and 4 on a down grade of 53 feet per mile. A representative of the committee riding on the engine would give the signal to the brake company's engineer when to apply the brakes, and immediately this signal would be transmitted by an assistant to the dynamometer, middle and rear cars. The distance was determined by measuring from the post to the engine cab.

The report of the committee gives the record of stops made

with the Westinghouse train of fifty cars at the brake tests of 1886 as follows:

Westinghouse Fifty Empty Car Train, 1886.

Automatic air-brakes.

No. Stop.	Speed.	Distance.	Shock.	Time.	Equivalent distance, 20	Equivalent distance, 40
621	23.5	424	Not taken.	17½	307	.....
611	20.3	354	"	16	340	.....
622	40	922	"	22½	.....	922
612	40	927	"	22¼	.....	927

At the brake tests of 1887 this record was much improved as regards quickness of application, and is reported as follows:

Westinghouse Fifty Empty Car Train, 1887.

Automatic air-brakes.

No. Stop.	Speed, miles.	Distance, feet.	Shock, inches.	Time, seconds.	Distance corrected for speed and grade, 20	Distance corrected for speed and grade, 40
511	19½	186	103	9¾	196	.....
521	19¼	215	70⅜	11	233	.....
522	36½	588	70½	17	.....	693

Attention, however, is particularly called to the terrific shock experienced at the rear of the train, as indicated by the movement of the slideometer. These shocks were so severe that only three stops were made with the Westinghouse atmospheric brake.

The portable electric valves were now added, the train remaining the same in all other respects. It was difficult to obtain any information regarding these electrical valves, but it is believed that two such valves were placed in the train, at the ends of the twentieth and fortieth cars respectively. As these valves operated practically simultaneously with the engineer's valve on the engine, it was equivalent to dividing the fifty-car train into five trains of ten cars each. The result of such tests are given as follows:

Westinghouse Fifty Empty Car Train, 1887.

Electric Application.

No Stop.	Speed, miles.	Distance, feet.	Shock, inches.	Time, seconds.	Equivalent distance corrected for speed and grade, 20	Equivalent distance corrected for speed and grade, 40
611	21½	160	None.	7	139	.....
531	23	183	"	8	138	.....
612	38	475	"	14¼	.....	519
532	36½	460	"	14	.....	545

This would indicate a reduction of over one-third in the distance required in which to stop a train moving twenty miles per hour, due simply to the introduction of two electrically actuated blow-off valves to expedite the reduction of the pressure in the main air-pipe, and thereby secure the quicker application of the brakes throughout the train. Furthermore, the introduction of these electric valves entirely eliminated all shock to the rear of the train. This is believed to be a most important consideration.

A similar record for the Carpenter brake shows as follows:

Carpenter Fifty Empty Car Train, 1887.

No. Stop.	Speed, miles.	Distance, feet.	Shock, inches.	Time, seconds.	Equivalent distance, 20 miles.	Equivalent distance, 40 miles.
751	22½	140	none.	7½	111	.....
811	23	150	none.	6¾	113	.....
821	23	133	none.	6	101	.....
752	32½	300	none.	11	.....	455
812	34	312	none.	12	.....	432
823	36	330	none.	11½	.....	407

The above figures would indicate that the improvements made in one year reduced the distance required in which to stop a train of 50 empty box cars from a speed of 20 miles per hour on a level from 301 feet to 101 feet, and a corresponding increase in the efficiency of the brake apparatus.

The average results of the brake tests at Burlington last May as reported by the committee to the Master Car Builders' Convention at Minneapolis is shown in the following table:

Kind of stop.	Name of brake.	Speed.	Distance.	Time. From brake applied by engineer. Rear car. Brakes begin to apply.	Time. From brake applied by engineer. Rear car. Brakes fully on.	Time. From full stop. Brakes off rear car.	Time. From full stop. Train moving.	Time. From release signal till full release rear car.	Number cars released by hand.	Train. Total weight engine, cars, and load.	Train. Per cent. braked.	Pressures. Before stop train pipe.	Pressures. Cylinder rear car.	Pressures. Brake beam pressure per cent. weight empty car.	Slideometer movement, rear car.	Couplings broken.	Miscellaneous brake casualties.	Wheels slid, distance.
		Miles.	Feet.	Seconds	Seconds	Seconds	Seconds	Seconds	No.	Tons.		Lbs.	Lbs.		Inches.	No.		Feet.
50 empty cars, air	Westinghouse	20	214	5	...	14	34	...	One.	866	93.4	73½	...	...	70⅜ to 103	One.		3
		40	693	9	...	...	...	...	One.	846	95.0	73	...	...	70½	One.		
	Eames	20	300	11	...	19¼	54¾	19	One.	742	94.5	20	12	91.4	18⅛ to 25½			23
		40	910	11	17½	19½	107	19⅓	Two.			19	10½	91.7	15¾ to 23¾			
	Carpenter	20	111	1⅛	4	1½	73	1⅓	One.	766	95.1	64	33½	98.5	None.			
		40	450	1¼	4½	2	69	1¼	Six			61	37½	100	None.			
50 empty cars, electric	Westinghouse	20	136	1½	3½	36	140	33½	Six.	846	95.0	73	...	...	None.			
		40	505	½	3½	40½	106½	39½	Two.			75½	...	...	None.			
	Eames	20	258	3	9	161¼	287	151½	None.	729	95.0	20	10¼	...	12½ to 913	One.	Dynamo and electric appliances gave considerable trouble, finally necessitating giving up a run.	18
		40	614	2¾	7	8	82	8				19½	10½	...	None.			
50 mixed cars (33 loaded, 17 empty), electric	Carpenter	20	169	1	3⅛	1	124	⅞	Three.	1,465	45.3	69	38	106.7	¼ to ¾		Four cars cut out for defects in electric valves, and one on account of broken brake rod.	16
		30	442	1	4	1½	113	1⅛				65	37	97.4	0 to ½			
	Westinghouse	20	183	1⅛	3⅛	59½	152¼	57½	One.	1,641	49.3	82	60½	...	None.		Brake would not release on one car, which was bled.	1
		30	438	½	4	79¼	460	74				83	61	...	None.			
	Eames	20	242	1⅛	6⅛	8¼	97	...	Six.	1,389	49.1	20½	12	92.5	None.		Difficulty in releasing, owing to low boiler pressure (105 lbs.) engine, six cars bled.	2
		30	516	2½	7¼	14	154	12				20	11	97.8	None.			
50 mixed cars (33 loaded, 17 empty), slack shoes, electric	Carpenter	20	133	1	3½	8	462	7¾	Several.	1,480	48.6	81	43½	123.2	0 to 3⅛		Electricity failed to stop train, owing to careless connection of wires on engine. One brake rod broken.	17
		30	334	1	4¾	8	168	8				74	48½	119.2	2½			
	Westinghouse	20	178	¾	4½	51½	146	50½	None.	1,641	49.3	85	63½	...	None.			17
		30	456	1	5	63½	162	48½				83	61½	...	None.			
Ditto, air	Eames	20	416	12	18	24¾	236	24	None.	1,399	48.8	20½	12	...	6 to 7	Two.	Two hose became uncoupled owing to being too short, and the load of wheels in two cars shifted.	
		30	751	12	24	34½	576	28				19½	11	...	0 to 5½			
50 mixed cars (33 loaded, 17 empty), air	Eames	20	407	11	15¼	26¼	123	26	None.	1,380	49.5	20⅓	12	97.6	3½ to 5⅛			4
		30	796	11	17⅔	35¾	177	35¾				19¾	11⅓	95.0	2 to 7¼			

NOTES.—Train pipe pressures are an average of those on engine and rear car. There was often from 5 to 10 lbs. difference in pressure between engine and rear car. Cylinder pressures given are on rear ca and are often considerably lower than those on front parts of train. Brake beam pressures are calculated from diagrams from Boyer Speed Recorder on middle car of train.

It is natural that in any brake-test the first question be as to distance required in which to bring a train to rest from a given speed. Most of the provisions of the committee seem to have been with regard to determining this. When the many different kinds of brakes originally entered at these tests are considered, this seems natural enough. These different brakes could be considered alike only in so much as all were intended to stop the train, and the distance in which this could be done would seem to be about the only ready means for the comparison of their efficiency. When, however, as was the case at the recent tests, the brakes are all practically limited to one class, and the only differences are as to the devices for controlling the pressure in the brake cylinder, it would seem almost absurd to refer to distance in which the train was stopped for purpose of comparison. Of course it is of considerable interest to know how quick and in what distance a train can be stopped from a given speed; still, when it is considered how much this is affected by the pressure carried in the train-pipe, the leverage used, the condition of the rail and the brake-shoes, and the many incidental causes entirely independent of the essential features of the respective systems, it will be seen what a useless basis of comparison such data become. With a train moving at the rate of twenty miles per hour, a difference of one second in the time of applying the brakes is equivalent to 29 feet in distance. In stop No. 821, the train moving with a speed of 23 miles per hour was brought to rest in 6 seconds and in 133 feet, or equivalent to 101 feet at 20 miles per hour. In other words, a difference of one second in giving the signal to apply brakes or in applying the brakes, would cause a difference of 25 per cent. in the distance required.

To show that very material variations of this kind probably did occur, reference will be made to the *Railway Review* of May 21st, where, in the report of the brake-tests, the following occurs: "In fourth stop brakes were not applied until after the engine had passed the post about 50 feet." This refers to Carpenter train stop No. 754, the record of which is given as follows: Speed, 41¾ miles per hour; distance, 569 feet; time, 16 seconds.

The importance of fractional seconds in such tests can be readily appreciated when one remembers that a train moving at the rate of 23 miles per hour is reported as being stopped in only 6 seconds. It seems very strange that in competitive tests of three different

brakes, all of which were controlled by electricity, and where electricity was used in so many different ways—for transmitting signals, for communication between rear car and engine by telephone, for recording time-marks on the different autographic records, etc., some simple electrical device was not connected with the handle of the engineer's brake-valve, to autographically record the moment the brake-valve was operated to apply the brakes, and thus eliminate from this most important record all possible error incident to personal observation and record.

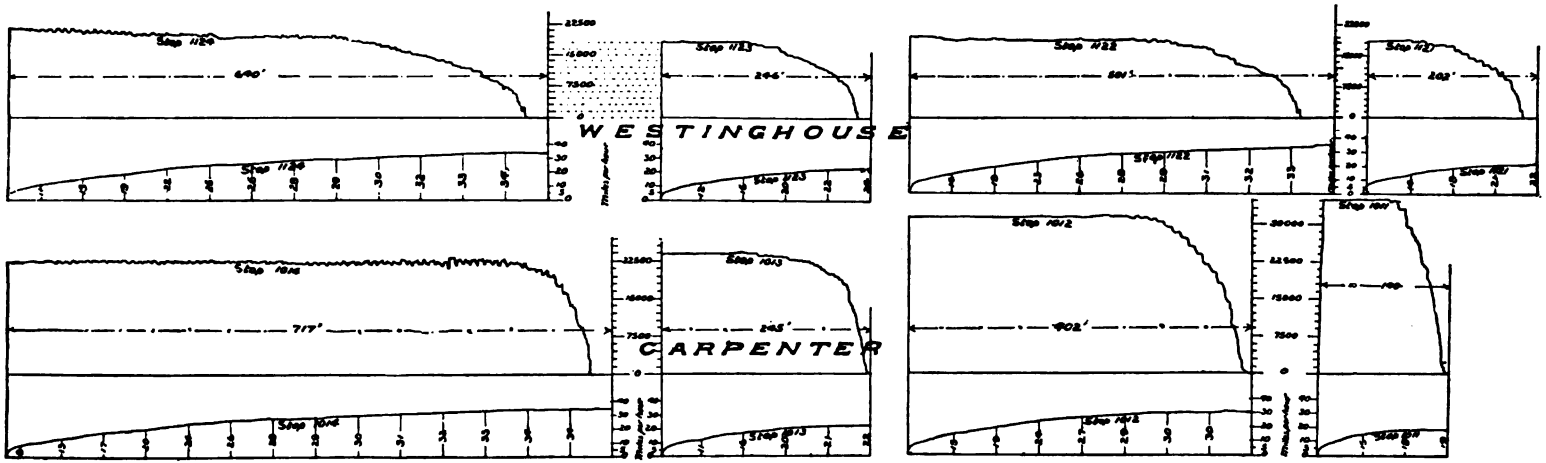
If we compare the Westinghouse and the Carpenter brakes as regards their efficiency in emergency stops, we find that these two brakes are or can be made identical in all respects except as to the valvular apparatus for controlling the communication between the auxiliary reservoir and the brake-cylinder, and the method of operating this valvular apparatus. Either brake system can be so arranged by modification of its constructive details with reference to the pressures carried in train-pipe, that when applied it will ultimately exert the maximum brake-shoe pressure allowable. The relative efficiency of these two brakes with regard to emergency stops will then be dependent entirely upon the rapidity with which this maximum pressure can be attained. In other words, to compare the efficiency of these two brakes, we need go no further than to compare the diagrams which would show the total pressure in all the brake-cylinders of the train at each moment after the handle of the engineer's valve is operated to apply the brakes, until the maximum pressure is attained. The committee arranged in the middle car of each train autographic apparatus for recording practically this very thing. With ordinary atmospheric brakes on a long train, the brake-pressure exerted by the brake-cylinder of the middle car would fairly represent the average throughout the train. This is also true with a brake, all the valves of which are operated directly by electricity, the operation of which are necessarily practically simultaneous. In the case of an atmospheric brake expedited in its action by a few electrically controlled valves in the train-pipe it depends in large measure on the location of these valves with reference to the car containing the recording apparatus. If, for example, the apparatus is located in the 25th car, and if the nearest electric valve is located on the 20th car, there being but one other electric valve in the train, located on the 40th car, as it is believed was the case with Westinghouse

empty car train tests, then such diagrams would probably fairly represent the average as before.

The following diagrams represent a few such records taken in the middle car at the Burlington tests. The vertical ordinate represents the brake-pressure at each moment during the stop. The horizontal movement of the diagram was proportional to the distance moved by the train. The commencement of this horizontal line is supposed to represent the point at which the brakes were applied. It may be interesting to consider a little more fully how this point was determined and recorded. A few seconds before reaching the stop-post a warning was transmitted by the electric signal bell to the middle and rear cars. On receipt of the signal from the committee's representative on the engine when the stop-post was reached, the brake company's engineer applied the brakes, while at the same time the assistant on the engine signalled the middle and rear cars by touching the push-button of the electric signal bell. On receipt of this signal in the middle car, the recording apparatus was thrown into gear, and the record paper moved beneath the recording pencils by suitable gearing connected with one of the axles of the car. The wheels of this axle were steel tired, carefully turned to exact dimensions, and were without brakes. The tension of the brake-rod was measured by the compression of a suitable spring, which was recorded by the vertical ordinate in the diagrams. The velocity of the train at each moment during the stop was likewise recorded by a pencil connected with a Boyer speed indicator. The starting of the paper record strip was supposed to correspond with the signal to apply brakes, as given by the committee's representative on the engine.

From these diagrams it will be seen, that with the Carpenter brake the pressure in the brake-cylinder commences practically simultaneously with the application of the brake on the engine, in all cases shown, except for stops 814 and 1014, in which cases it would appear that the brakes on the middle car did not commence to apply until about ½ second after the signal was given on the engine. With the Westinghouse brake, according to these diagrams, the brake on the middle car commenced to apply in about one second after the signal was given on the engine. This difference is readily accounted for when we remember that the valves of the Carpenter brake were controlled directly by electricity, and that therefore, the application of the brakes must necessarily be instan-

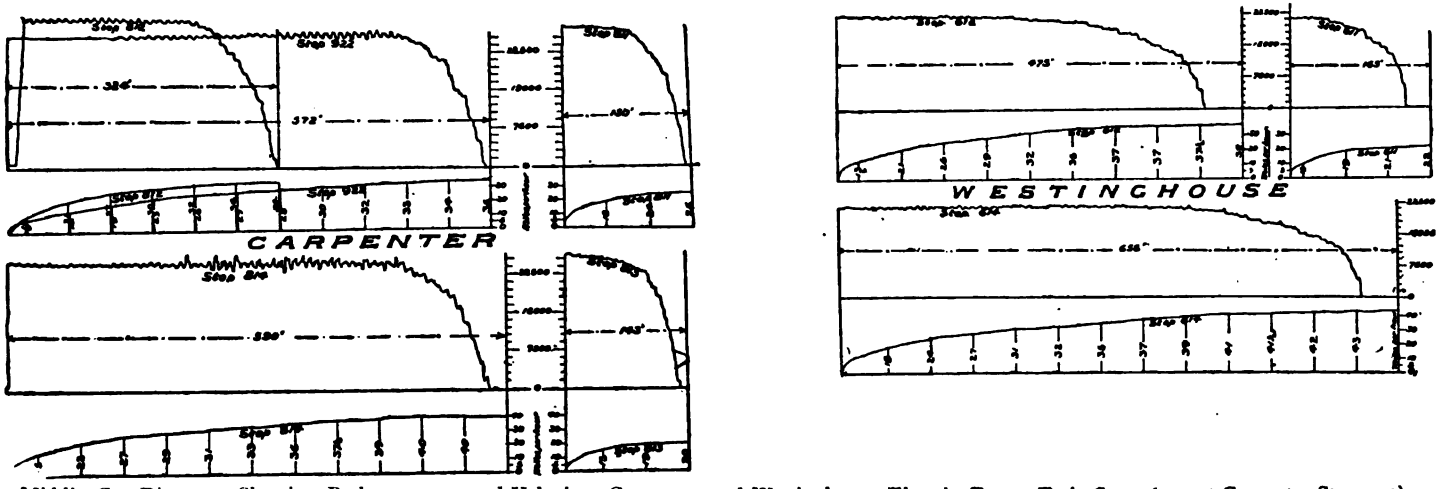
FIG. 1.



Middle Car Diagrams, Showing Brake-pressure and Velocity—Westinghouse Electric, and Carpenter Mixed Train Stops.

Figs. 1 and 2 are loaned by *Engineering News*.

FIG. 2.

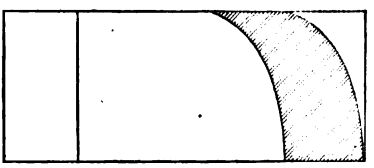


Middle Car Diagrams Showing Brake pressure and Velocity—Carpenter, and Westinghouse Electric Empty Train Stops (except Carpenter Stop 922).

taneous and simultaneous throughout the longest train, while with the Westinghouse brake the pressure in the train-pipe must first be reduced, thereby operating the triple valves to apply the brakes. With two electric blow-off valves in the train-pipe of a 50-car train this would be equivalent to the time lost in applying the brakes throughout a 10-car train equipped with the ordinary Westinghouse automatic brake with improved triple valve.

If we take the diagrams from two trains, all the incidental conditions being exactly alike, and place one upon the other, we would have a diagram something as in the following sketch; in which the efficiency of one brake over the other would be represented by the shaded area.

FIG. 3.



The foregoing diagrams readily show the advantage of the Carpenter brake as compared with the Westinghouse brake with electric attachments, as regards emergency stops at the Burlington tests. While the advantage here shown would not appear, at first glance, to be very great, still it must be remembered that this advantage is gained at a point where it is of the utmost, and sometimes vital importance. It is hard to conceive of a condition of affairs where a second or even fraction of a second is of more consequence than in case of an emergency on a railroad. With a train moving with a velocity of 60 miles per hour the loss of two seconds is equivalent to a distance of 176 feet. With another train approaching under the same conditions this would mean a loss of 352 feet, and while this might not be sufficient to avoid a collision, still the resulting damages would be considerably mitigated; by an amount in fact which would be represented by the work done by the friction of the brake-shoes through a distance of 352 feet.

With regard to the value of such quick emergency stops it has been urged by those opposed to the introduction of electrical appliances, that in practice such stops are required very rarely. It is true, and very fortunate for the travelling public, that such

emergency stops are not often required as compared with the number of service stops, but when one considers the value of life and property often depending upon such emergency stops their relative importance becomes apparent.

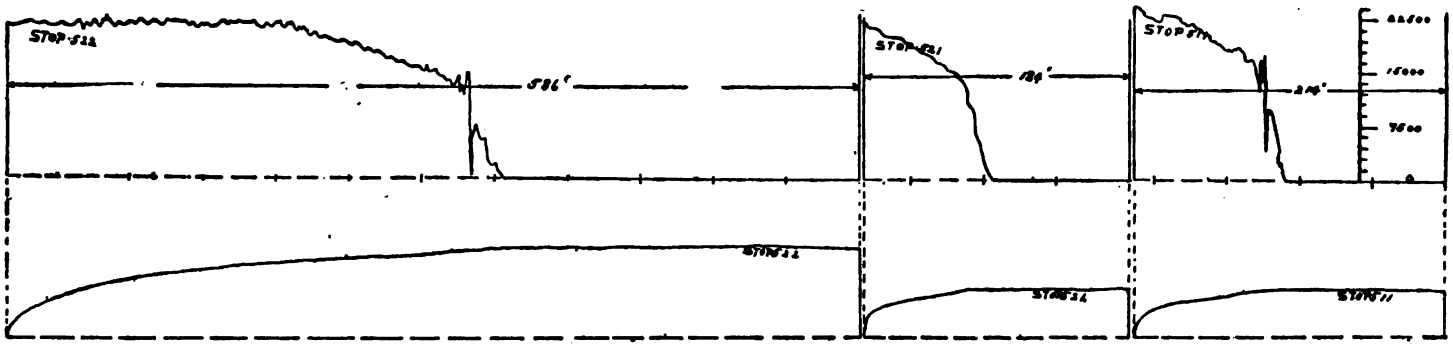
The accompanying diagrams are from the recording apparatus of the middle car for the Westinghouse non-electric 50 empty car stops 511, 521 and 522. These three stops were the only ones made with the Westinghouse air-brake without the electric attachments, and were accompanied by such terrific shock at the rear of the train as indicated by the movement of the slideometer of from 70 to 103 inches.

In stop 511 it will be seen that the brake on the middle car (which would represent about the average result throughout the train) did not commence to apply until the train had moved 110 feet beyond the point at which the brakes were applied on the engine, the train being brought to rest in a total distance of 214 feet. In other words, this represents a loss of 110 feet in making an emergency stop from a speed of 19½ miles per hour. In stop 521 in a similar manner 92 feet were lost out of a total of 184 feet, or just one-half of the total distance was sacrificed by the slow action of the improved "quick acting triple valve" used in connection with the Westinghouse brake at the Burlington trials. It was with this stop that the severe shock represented by a movement of the slideometer of 103 inches was experienced. In stop 522 the diagram shows a loss of 240 feet before the brake begins to apply on the middle car. This with an initial velocity of 36½ miles per hour.

These diagrams, it must be remembered, were made with the improved quick acting triple valves designed by Mr. Westinghouse, and certainly show a marked improvement when compared with similar diagrams from the brake tests of 1886, which were made with triple valves of ordinary construction, and practically the same as are now used in connection with the passenger train equipment of the country. These diagrams will enable us to form some idea of the action of the Westinghouse brake on a long passenger train of 15 coaches in ordinary service, with a ¾-inch train pipe instead of a 1-inch pipe as used at Burlington, and with the ordinary Westinghouse triple valves.

In the press reports of the recent frightful disaster near Piper City, on the Toledo, Peoria and Western R.R., it is stated that the

FIG. 4.



Westinghouse Air-Brake—Middle Car Diagrams.

engineer did not see the danger until within 100 yards of the fatal culvert or bridge. If this was so the engineer had 300 feet in which to check the velocity of the train. Do not these diagrams show that had the engineer of this train under such circumstances been provided with direct electrical control of the brake-valves throughout the train, the velocity and energy (which it must be remembered is proportional to the square of the velocity), of the train would have been materially checked and the consequent damage of property and loss of life proportionately reduced? It is true that, as before stated, such emergency stops are seldom called for in practice when compared with the number of service stops required, but they are sometimes called for, and in such cases the value of a few feet cannot be estimated.

Let us now consider these diagrams as compared with the table of average results as reported by the committee. According to this table, the time from applying the brakes on the engine until the brakes on the rear car commenced to apply, is given for the Carpenter brake as from 1 to 1½ seconds. None of the diagrams show a loss of more than ½ second, and it does not seem reasonable that the rear car, operated as it was directly by electricity, should be any slower in its action. In fact the loss of ½ second as shown by a few of the diagrams, merely represented the time lost by the engineer in manipulating the valve handle on the engine. From the arrangement of the brake it seems almost an impossibility that any appreciable time should be lost between the manipulation of the brake on the engine, and the operation of the inlet valve of the rear car of even the longest train. On the other hand, this table gives the same data for the Westinghouse electric brake as from ½ to 1 second. The last car was removed at least ten cars from the nearest electric valve. The above diagrams taken on a car not more than five cars removed from an electric valve, show a loss of not less than 1 second.

Another comparison may be made as regards the time till the brakes were fully on for rear car. This for the 50 empty car train stops is given for the Carpenter brake as from 4 to 4½ seconds and for the Westinghouse brake as 3½ seconds. This time was determined by readings from a gauge, and the difficulty of determining exactly when the maximum was reached may possibly account for the discrepancy of these records as compared with the middle car diagrams, which show for the Carpenter brake not

more than 3 seconds, and for the Westinghouse not less than 4 seconds.

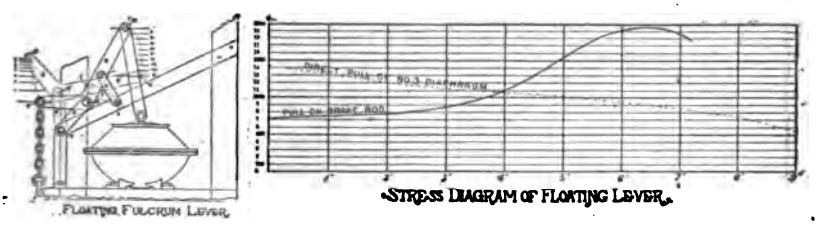
These diagrams are probably the most interesting of the numerous records taken at Burlington, and show clearly when compared with similar diagrams taken at last year's tests the very great improvement made in the efficiency of the brakes. They also show what room is left for further improvements in this direction. This would be represented by the area included between the ordinate from the point of application of the brake and the curve as now drawn. With the direct control of the valves as with the Carpenter brake, the operation of the inlet valves throughout the train is practically simultaneous with the manipulation of the engineer's valve handle. The rapidity with which the brake cylinders fill after the inlet valves are operated depends, first, upon the area of the valve opening and the length and cross section of the passages through which the air must pass from the auxiliary reservoir to the brake cylinder, secondly, upon the volume of the brake cylinders after the brake shoes are in contact with the wheels, and thirdly, upon the difference in pressure in the auxiliary reservoirs and the brake cylinders. The first can readily be so proportioned as to offer little resistance. The second depends upon the amount of slack in the brake gear, and can be reduced to a minimum by proper inspection of the cars while in service. The third could be taken advantage of by controlling the passage from the auxiliary reservoir to the brake cylinder by a cut-off valve, such that when the maximum allowable pressure is obtained in the brake cylinder this valve would cut off the further supply from the reservoir. Or a switch could be so arranged that when this maximum pressure is obtained the circuit through the inlet valve is broken, thus seating this valve. With such an arrangement it would be possible to carry comparatively very high pressure in the auxiliary reservoirs, and thus secure a very rapid filling of the brake cylinders. These are, however, refinements with which it would be undesirable to encumber the apparatus at present.

A much more important and desirable field for improvement in the event of the introduction of power brakes for freight trains, would be in the direction of proportioning the brake force to the load of the car. An ordinary box car weighs about 25,000 lbs. empty. This determines the maximum brake force allowable. When such a car is loaded its total weight is about 65,000 lbs., and

the brake force allowable without danger of skidding the wheels is proportionately great. With the brakes as at present in use, the loaded car receives no more brake-shoe pressure than the empty car, and its efficiency is proportionally less.

The Eames brake as tested at Burlington was to a certain extent arranged to meet this requirement. The brake-shoes were outside and hung to the body of the car, the loading of which compressed the bolster springs of the trucks and lowered the brake-shoes with reference to the wheels, thus increasing the stroke of the brake diaphragm. By means of the floating fulcrum lever as shown, the pull on the brake-rod increased with the stroke of the diaphragm, which varied with the load of the cars. Assuming that the brakes are properly adjusted and that the wear of the brake-shoes would be properly looked after, this no doubt would furnish quite an effi-

FIG. 5.



cient device. It would seem, however, desirable to render such a device independent of the wear of the brake-shoes. With the Eames diaphragm, the effective area, and consequently the direct pull of the diaphragm decreased as the stroke increases. This is also compensated for by the floating fulcrum lever, as shown in the stress diagram below.

If we wish to consider further the possibilities for increasing the efficiency of brakes, we must take into consideration the variation in the coefficient of friction between the brake-shoes and the wheel, as affected by velocity and time. The celebrated experiments of Captain Douglas Galton, made on the Brighton Railway, England, furnish us with the data for such consideration.

In the first place it was found that the friction between the wheel and the rail when the wheel is sliding on the rail, is less than one-third of the friction produced between the brake-shoe and the wheel when the brake-shoes are so applied as just to allow the wheel to continue revolving. This, besides the danger of ruining

the wheel by skidding, impresses the importance of preventing the use of too great a brake pressure.

It was also found from these experiments that the coefficient of friction between the brake-shoes and the wheel varied inversely with the speed of the train, thus allowing the application of a proportionately much greater brake pressure at high velocities, without danger of skidding the wheels. The following table shows the results of the experiments in this connection, as given by Captain Galton.

Coefficients of Friction at Varying Speeds.

Cast Iron Brake Blocks on Steel Tires.

Number of experiments from which the mean is taken.	Velocity.		Coefficient of friction.		
	Miles per hour.	Feet per second.	Extremes observed.		Mean.
			Max.	Min.	
12	60	88	.123	.058	.074
67	55	81	.136	.060	.111
55	50	73	.153	.050	.116
77	45	66	.179	.083	.127
70	40	59	.194	.088	.140
80	35	51	.197	.087	.142
94	30	44	.196	.098	.164
70	25	36½	.205	.108	.166
69	20	29	.240	.133	.192
78	15	22	.280	.131	.223
54	10	14½	.289	.161	.242
28	7½	11	.325	.123	.244
20	Under 5	Under 7	.340	.156	.273
	Just moving.		...	...	.330

Again, it was found that the coefficient of friction between the brake-shoe and the wheel at constant velocity varied greatly with the length of time the brakes were applied, as shown by the following table.

Coefficient of Friction as Affected by Time.

Speed, miles per hour.	Coefficient at commencement of experiment.	After five seconds.	After ten seconds.	After fifteen seconds.	After twenty seconds.
20	.182	.152	.133	.116	.099
27	.171	.130	.119	.081	.072
37	.152	.096	.083	.069	...
47	.132	.080	.070	...	
60	.072	.063	.058	...	...

The maximum retarding force which can be applied to a train is obtained when the brakes are applied with a force just below that which would slide the wheels. This, as we have seen, is dependent upon many circumstances. In practice it has been found, with the ordinary brake apparatus in use, that the safe limit to be allowed for brake-shoe pressure is about 90 per cent. of the weight of the wheel on the rail.

At the time of the Galton experiments, Mr. Westinghouse, seeing the important influence of velocity on the coefficient of friction of the brake-shoe, while at the same time the adhesion of the wheel to the rail practically remained constant, devised an attachment to his brake, which consisted practically of a weighing apparatus secured to the brake hanger, in such manner that when the friction of the brake-shoe exceeded a certain safe limit as determined by the compression of a spring, a valve was operated to reduce the pressure in the brake cylinder, and thus prevent sliding of the wheel. This would allow the application of greater pressure at high velocity, which was automatically reduced as the train was retarded. Though this apparatus is comparatively simple, and though devised some years ago, Mr. Westinghouse has not, it seems, found the advantages gained thereby sufficient to warrant its introduction in practice. During some of the recent tests at Burlington, however, this apparatus was applied to the engine brakes.

With the Carpenter brake the condition of the air in the train pipe is never disturbed while working the brake electrically, and in consequence the auxiliary reservoirs throughout the train can be constantly replenished and the pressure therein maintained at the maximum, even though the brakes are constantly applied with a greater or less degree of force. With the Westinghouse brake, however, while the brakes are applied, communication from the main reservoir and pump on the engine is cut off from the auxiliary reservoirs throughout the train, so that the latter cannot be replenished without releasing the brakes. In descending a long grade the brakes must be constantly applied and released, thereby depleting the auxiliary reservoirs. If an emergency stop should be necessary at the foot of such a grade, with the Westinghouse brake such stop could only be made with the diminished pressure remaining in the reservoirs, while, on the other hand, with the Carpenter brake the pressure would have been maintained in the res-

ervoirs, and as good a stop could be made at the foot of the grade as at the top, so far as such stop is dependent upon the pressure in the auxiliary reservoirs. Under such conditions, which are by no means unlikely to occur in practice, it would certainly seem that the Carpenter brake would have an advantage as to reliability.

To enable the Westinghouse brake to be used in descending long grades a pressure-retaining valve is provided for each brake cylinder. These valves are set by hand before descending long steep grades in such manner that when the engineer releases the brake to replenish his auxiliary reservoir, a pressure of 10 or 15 lbs. per square inch will be retained in the cylinders sufficient to keep the train under control.

In practice it is not only necessary that a brake be capable of stopping a train in the shortest possible distance, but it must also

FIG. 6.

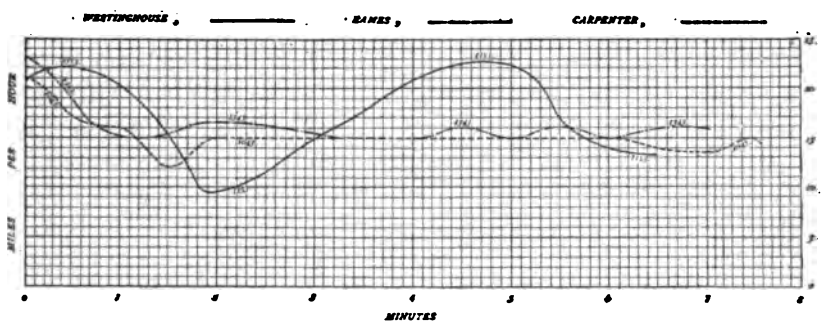


Diagram of Graduated Speed Run Down Grade.

put the train under the perfect and complete control of the engineer. At the Burlington tests of 1886 a number of so-called service stops were required. Such stops were omitted from the tests of 1887, but instead, a test was introduced to show to what extent the train equipped with the given brake was under the control of the engineer. This test required that a 50 mixed car train be let down a grade of 53 feet per mile, 3 miles long. Speed of 20 miles per hour at the top of the grade to be reduced to 15 miles per hour as soon as practicable, and maintained without material variation all the way down the grade. It will be seen that this is one of the severest tests of a brake, and the results of such test are given in the following table and diagram, which show the relative control of the train which each engineer had through his respective brake.

An engineer who can so control his train as to be able to let it down a 53-foot grade without any material variation in speed would certainly have no difficulty in stopping at a certain point, as a water tank, station, or the like, as is constantly required in practice.

Table of Graduated Speed Run Down Grade.

No. of Test.	Time, minutes	0	½	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
1023	Carpenter	20	19	18½	18	16½	16	16	14½	17	17½	18	16½	16	14½	14	...
1033	"	21	21½	20	18½	15	16	16	16	15	15	15½	15	15	15½	15	...
1043	"	21	17	16	12	15	15	14½	15	15	15	15	15	15	14	13½	15
1133	Westinghouse,	22	22	23	22	17½	14	14½	16	20	23	25	18½	12½	...	...	...
1143	"	20½	22	15½	9½	11½	15½	17½	21	22½	22½	17	15	13½	...	...	...
1413	"	22	23	25½	30	31	23	15½	17½	19	17½	16½	15	..	...	...	...
1423	"	21¼	23	27	27½	21	16	18½	18	19½	20	21	19	17¼	...	...	...
1233	Eames.....	20	16	15	15½	15½	16¼	14½	16	15	15	14½	...	...	...	...	...
1333	"	22	18½	15	15½	16	16¼	16¼	16½	15	16	16½	16	17	16	15	...
1234	"	23½	18½	15	15	16½	16	15½	15	15	16	15	16	15	15½	16	...

The importance of the automatic features of a brake become very apparent, when it is remembered that a large proportion of the accidents on our railroads are caused by freight trains breaking in two. To determine the action of the different brakes in this respect the committee made a series of tests by breaking a 50 car train between the 15th and 16th cars. A comparison of the results of such tests would be extremely difficult further than to state that all three brakes acted satisfactorily.

When we consider the numerous complicated conditions entering into the apparently simple problem of stopping a train, and compare the efficiency attained at the recent tests with the efficiency of a theoretical perfect brake on the one hand, and on the other hand, with the efficiency of the Westinghouse brake as tested at Burlington in 1886, one cannot but feel encouraged by the results.

Immediately after the regular tests at Burlington some special tests were made with a train of passenger coaches equipped with the ordinary Westinghouse brake. This train was estimated as equal to a train of two baggage, two passenger and four Pullman cars in ordinary running order. At a speed of 40 miles per hour, such a train, it was found, could be stopped in about 900 feet. When running at 50 miles per hour this would be equal to about 1350 feet, and at 60 miles per hour it would be equal to about 2000 feet. This probably represents the average efficiency of the ordinary passenger equipment at the present day, and shows considerable

room for improvement when compared with the records for the 50 empty car train emergency stops at the recent tests. The average distance for such stops with the Carpenter brake from a speed of 40 miles per hour, is given by the committee in their report as 450 feet, or just one-half the above figures.

The conclusions of the committee in charge of these tests are given in their preliminary report as follows:

"While we are not prepared to make any definite recommendation at this writing as to what freight train brake should be adopted, our present information, derived from the recent tests, point to two conclusions:

First. That the best type of brake for long freight trains is one operated by air and in which the valves are actuated by electricity.

Second: That this type of brake possesses four distinct advantages:

a. It stops the train in the shortest possible distance.

b. It abolishes shocks and their attendant damage to equipment.

c. It releases instantaneously.

d. It can be graduated perfectly.

The further question as to whether electricity is a sufficiently reliable element to use in freight train service can only be determined by experiment, but we think the benefits derived from electricity are so manifest that the experiment is well worth trying. In view of the foregoing and of the improvements that the buffer and atmospheric brakes are making, your committee recommend that the subject of automatic freight train brakes be continued for further investigation."

These statements evidently point to the Carpenter brake, and it would seem as though the committee were in doubt upon but one point in connection with such a brake, *i.e.*, the reliability of electricity in freight service. Such a question can certainly only be determined by experiment, but it would seem strange in view of the extended use of electricity at the present day if, with a little attention and study of the requirements, such devices could not be rendered perfectly reliable. The experience had with the Carpenter train at the recent trials certainly would encourage one in this belief. Besides, it must always be remembered that the electrical control of the brake is in addition to the control through the ordinary atmospheric appliances, so that in the event of any failure of the electrical appliances the brakes could still be operated by air until such electrical defects were remedied. Electricity in this connection is a new element, and it is but natural and proper that the men in charge of the motive power of our railroads should treat this subject with considerable conservatism. This, however, need not go to the extent of one of the editors of a leading technical

journal, who in an editorial on the subject says, "whether the electrical appliances will remain efficient during thunder-storms is extremely doubtful."

The advantages resulting from the use of electricity for operating and controlling pneumatic brakes have been clearly demonstrated by the results of the recent tests, and there remains only to show that these devices can be made reliable in actual service on our railroads. It is firmly believed that this will be done in the near future.

WHAT ARE THE REQUIREMENTS FOR A COURSE IN ELECTRICAL ENGINEERING AT A TECHNICAL SCHOOL?

BY F. R. HUTTON.

SEVERAL of the technical schools have recently established courses of study for the degree of Electrical Engineer, and it has been thought that a consideration of the nature and scope of such a course might be found of interest. It is with the intention of opening a discussion on this subject and presenting one view of the matter, that the following essay has been made.

It has been well said in recent discussions on the training of engineers, that the best education can only furnish the graduate with a kit of *well-sharpened tools*. That is, he should be taught principles and *how to study*, so that he can cope successfully with the variety of problems which will come in the diverse pursuits which the several members of the same graduating class are certain to encounter in their early experience. This is the better, higher and broader ideal of engineering education, as contrasted with the narrower and more material view at the other extreme, that education should not only furnish knowledge, but experience also, so that a graduate fitted for one special grade of labor can at once become an earner in that field. The difficulty, of course, with this latter plan, is that many men on entrance into school have not become differentiated or specialized enough for them to decide upon which side of the dividing hedges in the field of engineering their future special work will lie. This is also very often a matter decided by

the niches which are found or made for the graduate after his course is finished:—found for him by his professors by selection; made for him by influences which he has been able to command. Hence in discussing the requirements and training in a course in electrical engineering, it will be viewed from the broader basis with which the genius of Columbia College agrees, rather than through the narrower and more rectilineal lens which opens from the operative side of industry.

The course of study in any branch of engineering should make its graduate competent to become a leader in that work which he has to do. What, then, has the electrical engineer to do? What lines are open to him? The thesis which this paper seeks to establish is that the commercial field of the physicist-electrician *by itself* is very limited, and that except as combined with other specialties, cannot usually support its devotee. It is the view of the writer that the electrical engineer will be successful and a leader in proportion to his excellence and competency as a mechanical engineer, and that electrical engineering as a course should be built up upon mechanical engineering as its basis.

In establishing this position, the question must be propounded —What do we seek from our electrical engineer? The comprehensive reply is that we want from him an expert's counsel as to the ways of utilizing commercially and practically the supplies of available force which are manifested in electric energy. We recognize this energy as furnished by a beneficent Creator for the comfort and uplifting of his creatures, and the electrical engineer is to add to the sum of human happiness in so far as these reservoirs can be made to do industrial work at costs so low as to benefit even the poorest. Would not the mechanical engineer say in parallel terms, that his function was to bring *all* forces provided for man, so that tireless arms of steel may release the tired arms of human workers from toil, and so help every one to raise himself to a higher plane of life? Electric energy is but *one* of the many forces which the mechanical engineer should be competent to direct. The electrical engineer should, therefore, be first a mechanical engineer; and this is even more obvious if the less applied term of dynamic engineer be given to what is more generally known as the mechanical engineer.

Again, as we observe those who are called electrical engineers at this day, what do we find them doing? Their work can be

first divided broadly into the generation of electric currents, their transmission to the point where needed, and their industrial utilization at those points. The problems of the storage of electricity belong to the class of transmission problems, where the electromotor supplies energy which is given off at a distant point (distant either in space or time), and is paralleled by the use of compressed air or lifted weights in the purely mechanical field. The questions of pure transmission by wire or other conductors are entirely electrical, and make no demand for mechanical attainment. But they are of the simplest type, are easily mastered by persons of limited ability, and are of slight economic moment as compared with those of either generation or utilization of the currents.

It would be idle to waste space in proving that at this day the electrician who seeks to do industrial work leans hard upon the mechanical engineer for generating his currents. While battery currents will always be of importance for special cases, the armature of the dynamo must be set revolving by the skill of the mechanical man who has installed the motor driven by steam or water until thermal batteries have been devised, by which the oxidation of carbon shall produce the intenser currents directly, or until the atmospheric supplies can be tapped by our skill. In central station work of electric-lighting systems, mechanical skill of the highest order is called for to meet the questions of economical generation of steam and transmission of power. Again, in the third place, the industrial utilization of electric force transmitted from the motor, is obviously the department of an engineer, and (with the possible exception of electric lighting), of the mechanical type of an engineer. After all, in the present state of the art, the application of electricity to power commercially is the result of its capacities for easy transmission over long distances, its cleanliness, and its controllability at the point of consumption. In so far, therefore, as respects the motion which results where the electric energy is converted back, it might as well result from the motion of a belt, and the design would be of course in the domain of the engineer and mechanic. It appears, then, that were it not for the dynamo and motor with their connections, as two very important factors in the industrial train, the matter would be solely mechanical. It is these two matters which give the adjective "electrical" its significance in the degree and course of study, and these obviously are not the only ones of concern.

But, again, approaching the question from a third side, and carrying our inquiry into greater detail, in what capacities are electrical engineers engaged in their work? What positions do they fill? In the first place, they are inventors and patentees of electrical specialties. Supported by their own or others' money, they are engaged in laboratories in investigation and research, which result in favored cases in the discovery of new properties of materials, or of new combinations of commercial value. There are and must be but few of these who are successful, and their number must grow less as time goes on. The names of those who belong to this pecuniarily successful class can be counted on the fingers. Edison, Bell and Weston are types of such, but the necessary capacity for such work as they have done is not given to the average man. They may therefore be put on one side from the present discussion. The second class of electrical engineers include those who are manufacturers of their own or of others' patented inventions and specialties. As manufacturers and organizers of labor, as designers of special machinery and superintendents of their operation, they are obviously called upon to show mechanical skill, and their success will depend on the grade of this which they can show. The wealthy among the manufacturers are the capitalists, and their success is due to their business capacity and not to their scientific acquirements alone. It is in such companies as these that young engineers will try to begin their professional career. As physicists there will be a demand for a few only; as engineers and men of mechanical resource, there will always be room for them in the front seats. Such employees of companies constitute a third type of electrical engineers. They are superintendents of erection and installation, inspectors and testers of erected work, advisers and estimators on new work, designers of special methods for unusual cases, and do other duties of similar type. By far the larger number of educated young engineers are in positions of this sort, which call for electric skill of a high order, but that skill to be made available must be based upon an engineering basis of wide extent, largely mechanical and constructive. For such positions, which are the most available and interesting, the electrical engineers should be also and first mechanical engineers.

There is a fourth and last type of electrical engineers, who are men who figure as experts and consulting engineers, doing an

office practice largely. To this class belong also the patent experts and solicitors in electrical matters. Such men are usually physicists and men well grounded in theory, but are not often called upon to advise in constructive matters as engineers. The constructing companies have their own engineers and patent lawyers (which requires the legal training to be superadded), and the giving of expert testimony, while very profitable when in full swing, is not engineering in its highest sense. As in the first class of men, there will be but a limited number of detached consulting electrical engineers in the true sense, and they will be such only as have had long and successful experience in some of the other classes. A young graduate and novice would be likely to starve who began in this way by himself.

It would appear, therefore, that a course in electrical engineering should address itself particularly to the training of young men for positions in the second and third groups enumerated. This being conceded, it follows that they should be trained first as mechanical engineers, and upon that foundation erect the special electric structure. Let them be "mechanical engineers with an electrical engineering attachment," to quote from a sentence used by the writer in an informal conversation on this subject.

If the proposition of this paper be regarded as established, several practical consequences follow. These pages are not the platform for their full presentation, but among them, those interested may give thought to the logical embarrassment occasioned where a course in electrical engineering is created before the establishment of a fundamental course in mechanical engineering upon which it can be based; to the dependent relation of the instruction in electrical engineering upon the department of engineering in its broad sense; and to the necessary pre-existence of the mechanical laboratory for the satisfactory training of the electrical engineers. Or, finally (and this is the question to which the whole discussion has been intended to lead), would not the end be best subserved by making the course and degree of mechanical engineer in the university cover so much of electrical knowledge in addition to its other requirements as would render its graduates competent for the electrical positions which they are likely to be called to fill? This would make the mechanical course unique in scope and breadth, would make it attract the best, and would result in its exacting so high a standard in applicants for it as to make its graduates its best recommendation and advertisement.

NOTES ON THE ORE DEPOSITS, AND ORE DRESSING IN SOUTHEASTERN MISSOURI.

BY J. F. KEMP, E.M.

In the winter of 1885–86 the mill of the Desloge Lead Co. at Bonne Terre, Mo., was destroyed by fire. The property and remaining plant then passed under the control of the neighboring St. Joe Company, and the mill was not rebuilt. In the summer of 1884, during a two months' stay at Bonne Terre, I was permitted by Mr. Desloge, the manager of the works, to make a complete collection of samples to illustrate all the steps in ore dressing, for the United States National Museum, where they are now on exhibition. The following description of the process was also at that time forwarded to the Museum, and as the destruction of the mill removes all business objections to its publication it is now put in print, through the courtesy of Mr. F. P. Dewey, the curator of Metallurgy and Economic Geology.

In the deposits which can be profitably worked at the present time in Southeastern Missouri, the galena occurs disseminated through what was called by the Missouri State Survey, the Third, or Lower Magnesian Limestone,* a formation that is probably about the horizon of the Potsdam, or Calciferous † in the East. The mines are situated twenty-five miles west of the Mississippi River, and from forty to one hundred miles south from St. Louis, in Madison and St. Francois counties. In 1884 but three were in operation, the St. Joe (by far the largest) and Desloge, at Bonne Terre, St. Francois county, and Mine la Motte at the town of the same name forty miles south of the others, in Madison Co. Reports have recently been current (1887), of the discovery of further deposits at Mine à Jo, to the north of Bonne Terre. Although the Lower Silurian rocks of this region throughout nearly three thousand square miles seem to be pretty generally impregnated with lead, at present quotations only the largest mines can be profitably worked, but these are perhaps as extensive and uniform as any mines yet exploited for lead alone.

These deposits are totally different from the gash veins of the Mississippi valley, and with them they have no connection geo-

* Geol. Survey Missouri, 1873–74, pp. 30, 603, etc.

† Broadhead, G. C. Amer. Inst. Min. Eng., vol. v., p. 102.

logical or physical. The ore is locally and technically known as a "disseminated" ore. Galena accompanied by pyrite carrying nickel and cobalt is disseminated through certain strata * in greater or less richness, and seems to form as much an integral part of the rock as the crystals of dolomite themselves. The ore bodies fade out at their edges into barren rock, which may be succeeded farther on or below by other disseminations. The strata lie almost horizontal, and are known to carry lead through over two hundred feet in thickness. In the upper beds at Bonne Terre some chalcopyrite was met with, but during my stay no copper was present in the ore mined, although the iron pyrites made a valuable by-product for nickel and cobalt. At Mine la Motte, however, copper is more abundant, and nickel and cobalt form a very important part of the regular output.† The absence of zinc, whose presence is so marked a feature in the lead deposits of the later formations in the adjacent regions, is worthy of remark; in these disseminated beds it is entirely lacking. The St. Genevieve copper mines ‡ on the Mississippi are in beds of magnesian limestone placed higher in the geological scale than the Bonne Terre deposits, and their origin is ascribed to the process of dolomitization studied out by Dr. Schmidt § for the lead and zinc of the Joplin and Granby district. The lead and iron, cobalt, nickel, and copper sulphides of the three mines concerned in this paper were, however, doubtless precipitated from solution by the sulphurous products of decaying marine vegetation, and became mingled with and disseminated through the sediments of the early Silurian or Ordovician sea, as explained by Professor Chamberlain's || modification of J. D. Whitney's¶ theory. The only objection to be cited, is that the galena is very abundant, and any traces of fucoid remains, at Bonne Terre at least, very rare. The writer did find a few fossil remains

* Geolog. Survey, Missouri, 1873–74, l. c. Gage, J. R. Amer. Inst. Min Eng., vol. iii., p. 116. Broadhead G. C., Amer. Inst. Min. Eng., vol. v., p. 100.

† Neill J. W., Amer. Inst. Min. Eng., 1884–85, p. 634.

‡ Nicholson, F., Am. Inst. Min. Eng., vol. x., p. 444.

§ Missouri Rept., 1873–74, p. 412. Dr. Schmidt afterwards republished his thesis in Germany as a pamphlet for the students of the University of Heidelberg, where he is a Privat-docent. Die Blei und Zink-Erz-Lagerstätlen von südwest Missouri, Heidelberg. J. Hoerning, 1876. Cf. also Inaugural Dissertation of Erasmus Haworth for the degree of M.S., Kansas State Univ., June, 1884, on the Geol. of Cherokee Co., Kan.

|| Wisconsin Survey, 1882, vol. iv.

¶ Wisconsin Survey, 1862.

on the Desloge mine railway, that appeared to be such, and has been informed by Mr. Monell the metallurgist of the Desloge Co., that a fossil coral was found in the rear of Mr. Parsons residence, which was too poor for identification, but the rocks of the entire region are remarkably barren of all traces of life, the lingulas of a bed of sandy shale at Mine la Motte, being the only reliable palæontological data on record for their classification.

The ore bodies are therefore to be classed under the "Disseminated through Strata" group of Dr. Newberry's classification,* and resemble von Groddeck's "Typus Austin," † except that they are entirely lacking in zinc blende, and from their simple character would doubtless be made a Typus of themselves analogous to the Typus Commern, ‡ were the distinguished author familiar with them. I would add in addition to the references already cited, that an elaborate geological map and private report on the Mine la Motte property were made and printed some ten or fifteen years ago,§ and references to the mines are naturally not infrequent in the current journals and reports on Mineral Statistics.

The ground is kept fully prospected by the diamond drill. The ore is mined by the pillar method, and the mining operations are exceedingly simple, being little else than the underground quarrying with Rand drills of a soft, yet firm rock. The hanging is supported by pillars left at suitable intervals, but immense spans, forty to sixty feet high, and one hundred feet or more between supports stand with perfect safety. Very little water is encountered.

The methods of ore dressing differ somewhat at the three mills. Sizing is carried further at Mine la Motte than at the others, while at St. Joe the process is quite different from the other two, and has reached its present form through the many ingenious devices of the superintendent Mr. Parsons, whose new mill exhibits one of the largest, as well as lightest and most convenient ore dressing floors to be seen at home or abroad. In Missouri, the crushed rock, and particularly the tailings are known as "chats," the middlings, consisting of a mixture of galena and pyrite, are called "sulphur" by the mill men, and the heads, or pure galena, are called "mineral." What is taken from the jig sieves with a shovel

* This JOURNAL, vol. i, p. 98.

† Die Lehre von den Lagerstätten der Erze, p. 103.

‡ Die Lehre von den Lagerstätten der Erze, p. 101.

§ A copy is in the St. Louis Public Library.

is called in the following, "sievework," and what goes through and is tapped out below, "hutchwork."

The Desloge mill consisted of one main building for the general treatment, and one auxiliary smaller building for slime treatment, known as the "Old Mill." In the main building there were four sets of jigs, which I have called (*a*), (*b*), (*c*), and (*d*).

Set (*a*) has two sieves, called in the following (1*a*) and (2*a*) respectively.

Set (*b*) has two sieves (1*b*), and (2*b*).

Set (*c*) has three sieves (1*c*), (2*c*), and (3*c*).

Set (*d*) has three sieves (1*d*), (2*d*), and (3*d*).

The numbers in the schemes refer to the following notes, in which the individual steps are more fully set forth.

(1.) Blake crushers, 15 inches by 9 inches feed orifice, 150 revolutions.

(2). Coarse rolls; six pairs, three directly after the crushers, three for rock rejected by the 9 m.m. screen; 14 inches face, 30 inches diameter, 12 revolutions per minute. They consisted of a chilled cast-iron tire 6 inches thick on an interior coned hub, fastened by wedges and keys. They were run by gearing with long teeth, to allow for the play, and held up against each other by rubber springs. They are made by the Missouri Car Wheel Foundry, St. Louis.

(3). Elevators; three in use, one to each crusher. They take the crushed rock to the top floor to give it the necessary fall to complete its journey. The buckets are 6 inches wide by 5 inches deep by 9½ inches long, wedge-shaped, bolted to the belt by small bolts and nuts, and calculated to hold 12 pounds each.

(4). Nine m.m screens; three in use, 3 feet diameter, 8 feet long, 16 revolutions per minute, slope about 1 in 10. Run by gearing with extra long teeth, to allow for the incline. Screening done dry.

(5). Seven m.m. screens; three in use, 3 feet diameter, 5 to 6 feet long, 18 revolutions. Run by belting.

(6). Jigs (*a*); three pairs of two-sieved, end lever jigs, and one large four-sieved Collom jig. End lever jigs, sieve 18 inches by 30 inches, No. 8 wire, bed 5 inches deep, automatic Rittinger discharge, giving from sieve 1*a* good mineral, and from sieve 2*a* rich chats, that are afterward crushed in special fine rolls. Strokes, 110 per minute. Approximately ⅞ inch stroke. With rich rock

at the crushers there is no hutch-work and no tailings from these sieves. The estimated capacity is one ton per hour each.

(7). Classifiers; three in use, one to each screen. They are boxes, with a properly regulated rising current of water.

(8). Jigs (*b*); 12 two-sieved end lever jigs. No. 1*b* gives good mineral, 2*b* sends rock to recrushing rolls, with discharge of 2*a*. Both sieves are automatically discharged. The sieve is 18 inches by 30 inches, No. 15 wire, 120 strokes per minute, ⅞ inch to ⅝ inch length of stroke, bed 5 inches deep. There are no tailings from second sieve with rich rock. The estimated capacity is 15 to 20 tons in twenty-four hours from each jig.

(9). Jigs (*c*); two series, each containing four three-sieved eccentric jigs. First series, 150 strokes, and second, 160 strokes; sieves, 14 inches by 36 inches, No. 15 wire on 1*c* and 2*c*, and No. 20 on 3*c*. The stroke is approximately ½ inch. The sieves are cleaned with a shovel. There is very little hutch-work. Sieves 2*c* and 3*c* are called sulphur jigs, as they yield pyrite. The second series was run a little faster, as it received the hutch-work of 2*c* and 3*c* of first series. The estimated capacity of each jig is 10 to 15 tons in twenty-four hours.

(10). Recrushing rolls; two pairs in use, 14 inches face by 30 inches diameter, 24 revolutions. Each pair crushes from 40 to 50 tons of chats, 9 to 5 m.m. down to 3 m.m. and less, in twenty-four hours. The 3 m.m. screen is 3 feet diameter, 8 feet long, makes 18 revolutions, and is run by a belt whose breadth neutralizes the incline of the pulley.

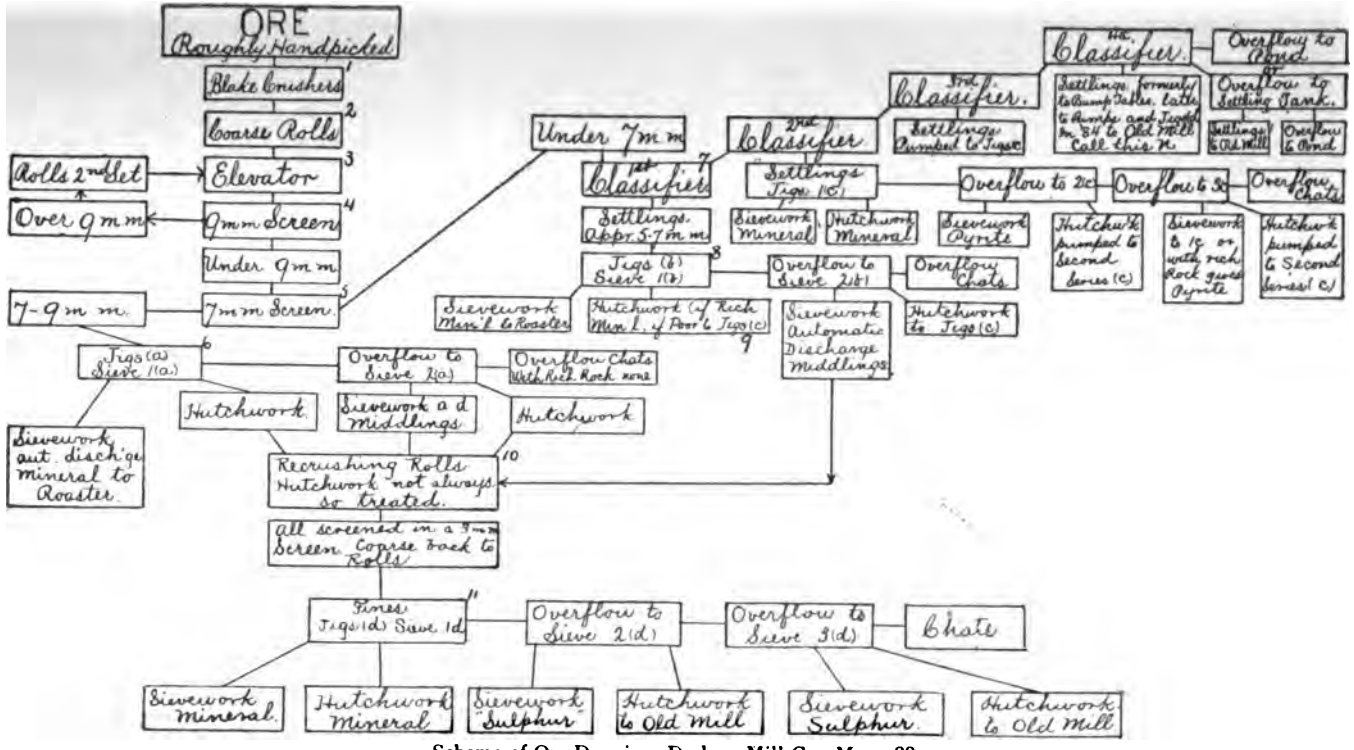
(11). Jigs (*d*), known as sulphur jigs; there are two series, with four three-sieved jigs in each. The size, speed, and stroke are the same as for jigs (*c*).

The chats or tailings from all these jigs are run by water into railway cars, and hauled away.

(12). *The Old Mill.*—This was a small old building, and was the mill of the company in its beginning. It was refitted for slime treatment and the recrushing of any chats that happen to be rich. The rolls were similar in every respect to those described under 10. The Old Mill also contained a pug mill, with a settling tank and a second Evans table, for working over the tailings of the old Rittinger bump tables formerly employed.

(13). Jigs (*e*); there were two two-sieved end lever jigs; sieve 18 inches by 40 inches, 140 strokes, and two three-sieved eccen-

FIG. 1.

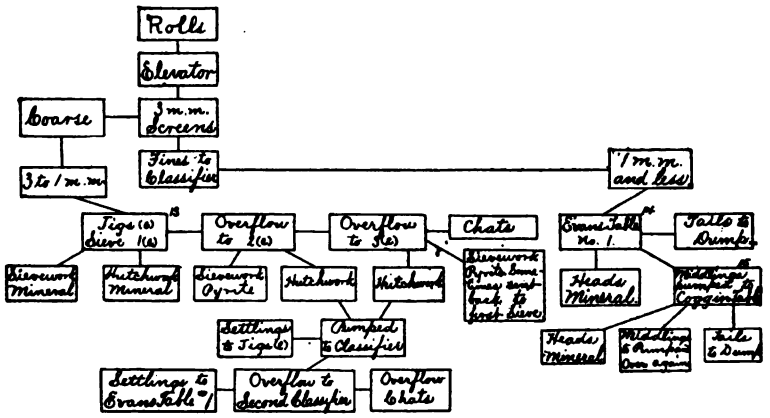


Scheme of Ore Dressing, Desloge Mill Co., Mo, 1884.

trigs, sieve 14 inches by 35 inches, 160 strokes. They both treated the same material. The three-sieved jigs were similar to jigs (*d*) second series; see section 11, above.

(14). Evans table, No. 1; 18 feet diameter, deadhead or apron 9 feet diam., slope, 11 inches in 9 feet, 1 revolution in 80 seconds.

FIG. 2.



Old Mill, or Tail House (12). (Receives hutchwork of 2 (*d*) and 3 (*d*) from centrifugal pump "*N*," and rich chats in car loads.)

(15). Coggin table; a convex table with no apron, 19 feet diamter, slope 1⅜ inches to the foot, 1 revolution in 60 seconds.

The second Evans table, following the pug-mill, was 20 feet in diameter, with a 5-foot apron, slope 1⅜ inches to the foot, 1 revolution in 55 seconds.

The Desloge mill was designed by F. de Strovlinski, the engineer of the Fort Scott Iron Works, Fort Scott, Kansas. In its original design the sizing was carried further by means of more screens, and the speed of the jigs was different, and in all cases higher. The wear and tear of screens induced Mr. Desloge to size less closely, and do the extra work on the jigs. The Desloge system was one in which sizing was carried to a considerable extent, more than at St. Joe, but less than at Mine la Motte.

In the National Museum the process at St. Joe is also fully illustrated by samples taken at every step, as well as by manuscript notes, while the Mine la Motte is simply represented by manuscript. It may be said, however, that the conditions at each mill affect the process chosen, and the problem is this: at Mine la

Motte, with far smaller capacity, they size closely and aim at clean tailings, as in the German ore-dressing works. At St. Joe, with immense deposits underground and low prices for lead, they esteem it advantageous to treat an immense quantity—800 tons of rock per day in 1884—with a simpler process, sacrificing, it may be, a small amount of galena in the tailings.

SOME CAUSES OF ERROR IN BLANK ANALYSES.*

BY J. B. MACKINTOSH.

IN making chemical investigations it is quite usual to run a blank analysis in order to apply a correction to our results for the impurities contained in the reagents and for those entering into solution from the apparatus used. As a rule, however, it seems to be entirely overlooked, that the conditions of the actual analysis are often quite different from those obtaining in the case of the blank. For instance, let us assume the case of a limestone which has been dissolved in just sufficient hydrochloric acid to form a neutral solution of calcium chloride; at this stage our blank analysis will be a strongly acid solution. If we now add to both, enough ammonia to neutralize the amount of hydrochloric acid previously employed, we will have in our actual analysis a strongly ammoniacal solution, while in our blank there will be a neutral solution of ammonium chloride, and similar results will take place on the addition of every reagent. In such a case our blank analysis will give us only approximately correct results, for though any impurities existing in the chemicals will be detected, yet the impurities which are dissolved from our beakers by the solutions will be quite different in the case quoted, and the errors due to this last source may far exceed those due to impurities contained in the chemicals used.

The particular case of blank analysis to which I desire to call attention, serves to illustrate the serious error into which chemists

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may be led by faith in the infallibility of books of reference, whose statements, copied from one another, gain in authority through force of iteration, even though, as sometimes is the case, the original statement be erroneous.

Several years ago I had occasion to analyze a large number of samples of metallic copper and alloys of copper, and for the determination of arsenic I decided to use the method of distillation with ferric chloride and hydrochloric acid recommended in Crooke's *Select Methods*.* In that work the statement is made, that the ferric chloride employed may be freed from all traces of arsenic by one or two evaporations to dryness with hydrochloric acid, whereby the arsenic will all be volatilized as chloride. In following these directions I collected the distillates, thus making a blank analysis in all respects similar to the actual analyses performed later. When the distillates were tested for arsenic they were found to be perfectly free from that element, from whence the deduction was drawn that the reagents employed were pure. If the statement mentioned above was correct, then this deduction was justified by the facts observed. I noticed, however, that all the samples of copper I had, no matter of what quality, invariably caused the appearance of large quantities of arsenic in the distillates, and on repeating the experiment with the substitution of some charcoal for the copper, I likewise obtained arsenic in the distillate, and since the charcoal could not be suspected of being the source of the arsenic found, it was definitely traced to the ferric chloride, which, by a blank analysis would have been pronounced pure. In this case, the omission of the copper in the blank analysis was also the omission of a necessary reagent, without which or some substitute, the reaction would not take place. In fact, it is not until the arsenic is reduced to arsenious chloride that it will distil off, any arsenic in the higher form of oxidation not being volatile under these circumstances.

Here is a striking instance of the unreliability of blank analyses, unless all the circumstances be thoroughly comprehended and taken into account, and other instances of similar nature could readily be adduced.

LEHIGH UNIVERSITY, SOUTH BETHLEHEM, PA.

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* First edition, p. 266. Second edition, p. 431.

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PROFESSIONAL NOTES.

Mining Cases:

A mining case of some interest has recently been decided in Alaska. One of the questions involved was as to the sufficiency of location of a placer claim. The defendant located a placer claim, so that it overlapped a previously located quartz claim. The placer claim was located without reference to any natural object or permanent monument and without any designation or mark by which it could be identified. There were no local rules requiring a record of the location, and the locator of the placer claim simply recorded the location in his memorandum book. The locator of the quartz claim began suit against the locator of the placer claim, who set up that he and his co-prospector, one Ileneau, had held an election under the provisions of the Act of Congress of May 10th, 1872, in the presence of three Indians, who could neither speak nor understand English, at which election he, defendant, was elected recorder for the mining district to which he gave his own name. It was held that the record in the defendant's memorandum book was not such a record as would comply with section 2324 of the Revised Statutes. (Act of May 10th, 1872). This amusing case is entitled Fuller *v.* Harris, and is found in vol. 29 Federal Reporter, page 814.

The Supreme Court has decided another apex case, the Argentine Mining Co. *v.* Terrible Mining Co., 122, U. S., 478. This case, however was not decided on priority of locations, or on the existence of the apex in the defendant's land, or continuity of the vein, or on any other such vexed question, but on the ground that the defendant, instead of locating his claim lengthwise *along the vein or lode*, had located it across the vein or lode, and what the defendant had insisted were side-lines, the longer lines of his claim, were in reality end lines. The defendant had followed down the vein outside of his longer lines, between planes drawn vertically through his shorter, or as he called them, end lines, and taken mineral from the plaintiff's land. He was held liable in damages and possession was awarded to the plaintiff. The Court says, "it was not the intent of the law to allow a person to make his location crosswise of the vein so that the side lines shall cross it, and thereby give him the right to follow the strike of the vein outside of his side lines. . . . . The end lines are those which measure the width of the claim as it crosses a lode. The side lines are those which measure the extent of the claim on each side of the middle of the vein at the surface." This case affirms Mining Co. v. Tarbet, 98 U. S., 463. W. P. B.

Column Formulæ:

In the general specifications recently drawn up for the Bridge and Construction Department of the Pencoyd Iron Works, by their chief engineer, Mr. C. C. Schneider, occurs this statement: "For compression members, these permissible strains of 14,000 and 18,000 lbs. per

square inch" (for wrought iron and steel respectively), "shall be reduced in proportion to the ratio of the length to least radius of gyration of the section, by the following formulæ:

$$\text{for wrought iron } p = \frac{14{,}000}{1 + \frac{l^2}{15{,}000\, r^2}}$$

$$\text{for steel } p = \frac{18{,}000}{1 + \frac{l^2}{10{,}000\, r^2}}$$

where, p = permissible working strain per square inch in compression,
l = length of piece in inches, centre to centre of connection,
r = least radius of gyration of the section in inches."

It will be seen that the above formulæ do not differ in general character from Gordon's formula, but a comparison shows an endeavor to account for the relative behavior of steel and iron under compression: to duly consider the fact of the greater unit compressive strength of steel over iron in short numbers, and also the fact of its coefficient of elasticity being the same.

The two formulæ conform to the results of experiment, that at about the value of $\frac{l}{r} = 200$, steel and wrought iron columns have the same strength. How well they give the relative strengths of columns in the two kinds of material for less length ratios, is yet to be determined by experiments, but that they are an advance toward establishing the true relations of iron and steel columns can hardly be doubted, and the writer believes this to be one of the best, if not of the first attempts to introduce into actual practice a general formula by which the working strength of steel columns at all length ratios can be calculated, independent of comparison with an iron column of equal size.

It becomes then a matter of interest to learn the basis on which these formulæ of Mr. Schneider's are founded. In a recent conversation he attributed them to the method devised by Professor R. Krohn, and explained by him in a paper entitled, "New Formula for Compression Members," printed in the *Transactions of the American Society of Civil Engineers*.

Professor Krohn's method of deduction is in general, to assume at the outset, the existence of eccentricity of application of the load from the axis of the column; to ascertain an expression for the stress in the outer fibres of a member, if it were in compression, and a similar expression for it in tension with the same eccentricity, and take their ratio.

Then, assuming the stress in the outer fibres the same in compression as in tension, he gets an expression for the safe compressive working stress in terms of the *extreme value* of this ratio, and the allowed tension working stress.

The method is so well reviewed in the *Minutes of the Institution of Civil Engineers*, vol. xxxviii., p. 463, that we quote the review, adding thereto a few of the formulæ, and also calling attention to the fact that Professor Krohn's analysis, which assumes hinged ends, agrees with Mr. Schneider's past practice of assuming such connections in all his calculations of compression members of bridges. . . . . "The object of the paper is to suggest a method by which the permissible working stress for compression members may be determined upon rational principles.

The author remarks upon the imperfections of the well known formulæ that have been deduced for this purpose, either upon theoretical grounds, or from experimental data. Theory indicates that if the pressure of the load acts directly along the axis of the column there can be no deflection, unless the load exceeds a certain fixed quantity; and that so long as the load is kept below this limit, the column is only strained by direct compression, and suffers no bending stress. But this deduction is contradicted by the general results of experiments, which show, that in practice, the column begins to bend slightly with even a moderate load, and is actually ruptured by a load which, according to theory, should be insufficient to produce any deflection.

This discrepancy proves the incorrectness of the assumption on which the theory is grounded, viz., the assumption that the pressure acts exactly in the line of the column's axis. In practice it is impossible to fulfil this ideal condition; for even in carefully prepared test-pieces, it will be interfered with by unavoidable imperfections of workmanship, and inequalities of the material, and to a still greater degree in the case of practical bridge members.

It would therefore appear more reasonable from the first to assume that the straining force will be applied in a line more or less eccentric to the axis of the column. The calculated strength would then depend upon the extent of the assumed eccentricity, and the question arises, whether it is possible to determine that quantity.

It is evident that the initial eccentricity is subject to no definable law, and experiments indicate that it varies widely in different cases; so that it will only be possible to rely upon a certain lower limit of strength, corresponding to the greatest extent of eccentricity that is likely to occur in ordinary practice.

The author considers that it would be a difficult task to determine this limit. For such a purpose it would be useless to refer to the usual tests, which are carried to the crippling point; and reference could only be made to the deflection of struts as observed when the fibre strain is within the elastic limit. But if a maximum eccentricity were deduced in this way from any particular series of tests, it could hardly be taken as a maximum applying to all cases.

In view of this difficulty the author proposes to treat the question by analogy with the case of tension members

Whether a member is intended to be used as a strut or as a tie, the same care will be taken in the selection and manufacture of its component parts, and there is no reason to suppose that the unknown eccentricity is any greater in one case than in the other; although its effect in the case of the tie is commonly neglected, or is, at all events, covered by the usual factor of safety. The additional fibre strain produced by a given eccentricity is, of course, greater in the strut than in the tie; but the author claims that the ratio between the fibre stresses in these two cases can be determined, and that the working load for struts may then be fixed with the same degree of security as in the case of tension members.

Accordingly, an approximate formula is found for expressing the greatest compressive stress C, in the extreme fibres of a strut having a certain eccentricity a; and the tensile stress T, in the extreme fibre of

a tie having the same eccentricity, is expressed by another formula. Then the ratio between the extreme compressive stress, and the extreme tensile stress is, of course, denoted by $\frac{C}{T} = n$.

Therefore, if it may be assumed that the strength of the material is the same in compression as in tension, the working load for struts must be one-nth of the working load for ties, in order that the extreme stress may have the same intensity in both."

From the ratio $\frac{C}{T} = n$, and the formulæ mentioned above, giving the values of C and of T, the author obtains,

$$n = 1 + \frac{\frac{1}{8}\frac{l^2 P}{EI}}{1 - \frac{1}{8}\frac{l^2 P}{EI}} \times \frac{\frac{a e}{r^2}}{1 + \frac{a e}{r^2}}$$

P = total force applied.
E = coefficient of elasticity.
I = moment of inertia.
l = length.
r = least radius of gyration.
e = distance of extreme fibre from the neutral axis.
a = the original eccentricity of application of the force.

The fraction $\frac{\frac{a e}{r^2}}{1 + \frac{a c}{r^2}}$ can never be greater than unity, whatever value the original eccentricity a may have.

Therefore the upper limit of the value of n is

$$n = \frac{1}{1 - \frac{1}{8}\frac{l^2 P}{EI}}$$

By maintaining this ratio between the working stresses in tension and compression, the eccentricity for compression members can be neglected equally well as in practice it is done for tension members.

Calling $k = \frac{P}{S}$, the allowed unit stress for tension members, the allowed unit stress in compression members will be $\frac{P}{S} = \frac{k}{n}$.

Hence, $\frac{P}{S} = k\left(1 - \frac{1}{8}\frac{l^2 P}{EI}\right)$

Substituting for I, its value Sr^2, the author obtains the final formula

$$\frac{P}{S} = \frac{k}{1 + \frac{1}{8}\frac{k}{E}\frac{l^2}{r^2}}$$

This formula differs from Gordon's formula as modified by Rankine, in using $\frac{k}{E}$ as the coefficient of $\frac{l^2}{r^2}$, instead of using a constant.

It is from this formula that Mr. Schneider derived the special ones given in his specifications, taking E = 26,000,000 pounds, and k as before stated. **

Effects of Heat upon the Strength of Iron.

Professor De Volson Wood read a short paper before the Mechanical Science section of the American Association for the Advancement of Science at its recent meeting, relating the results of his experiments on subjecting wrought iron to tension and heat at the same time. The experiments were suggested by the burning of a loaded oil train while standing upon a bridge.

Two sets of experiments were made with small bars of equal size, and an ultimate tensile strength of 50,500 pounds per square inch.

Several were heated to a dull but decided red heat, and while in that condition subjected to a pull of one-fifth the ultimate strength, equal to 4700 pounds per square inch. This stress was maintained for fifteen minutes, until the specimens were cooled off.

When cool, the bars broke at a mean ultimate strength of 49,705 pounds.

In the other set of experiments the heated bars were subjected to a continued pull of 5700 pounds, equal to about one-fourth their ultimate strength, and when cooled, they gave a mean ultimate strength of 50,026 pounds.

Professor Wood explained the greater ultimate strength in the last case, by a comparison of the records of action of the individual bars, and concluded that one set of bars were heated to a higher point when put into the machine than were the others.

His final deduction from the results given by the twelve bars experimented upon was:

If wrought iron be heated to a dull red, and while hot, be pulled to an amount not exceeding one-quarter of the ultimate strength, the strength of the iron will not be interfered with. **

Bridge Pins.

The bridge that is to be erected at Cairo for the Illinois Central Railway, from designs by Mr. George Morison, is to have steel members throughout.

It will be distinguished by two of the longest spans of the Whipple type in the country, 518 feet each. In addition to these, there will be seven 400-feet and three 250-feet spans of the same type. All will be through spans.

A peculiarity that Mr. Morison has adopted for this and several other important bridges now building, is the boring of a hole for a $1\frac{1}{8}$-inch bolt through the axis of all steel pins of 4 inches and over in diameter.

The pins are not to have nuts, but a plate will be held against each end by the bolt. Mr. Morison's object in boring out the centres of the pins is to relieve the initial strains caused by casting and subsequent working. **

ABSTRACTS.

A Crystalline Subsulphide of Iron and Nickel.

Some months ago I received a sample of a highly crystalline product occurring in the hearth of the shaft-furnace used in smelting the roasted niccoliferous pyrrhotite at Mr. Joseph Wharton's works near the Gap Mine, Lancaster County, Pa.

Mr. Wharton first observed this product in cavities in the concretions in these furnaces about the year 1870, and published a description of it in that year.* Thinking that it might show some analogy to meteoric iron, he sent the present sample to Mr. George F. Kunz, who turned it over to me, with the request that I should analyze it at my convenience. The results do not show the expected analogy, because the sulphur in meteoric iron is combined as FeS, while in this product there is only one-sixth the necessary amount of sulphur, which, however, seems to be combined with all the metallic elements present, forming a sub-sulphide of definite composition. I am informed by Mr. Wharton that he has had for a long time the sample which I have analyzed, and that it probably is about the same age as that which he first described. It is worthy of note that the material does not show any signs of oxidation, but that the crystals preserve a brilliant metallic lustre.

The first two analyses, made by Mr. J. Voigt, are those given by Mr. Wharton in his paper above referred to; the third is the analysis I have just completed.

	Voigt. Octahedral Crystals.	Granular mass.	Mackintosh. Cubical Crystals.
Cu,	1.85	1.74	2.20
Ni,Co,	25.22	28.20	26.16
Fe,	64.10	62.50	61.685
S,	8.90	7.60	8.305
SiO_2,	.....	.....	0.56
	100.07	100.04	98.91

Theoretical for Fe_4Ni_2S.

Ni,	31.29
Fe,	60.12
S,	8.59
	100.00

In my analysis there is a small amount of silica which is present in mechanical admixture, in the form of slag or furnace-lining. The deficiency in the analysis is due to the other constituents of this admixture. In the granular mass, the sulphur is deficient; but as it *was* a granular mass, on which the octahedral crystals were imbedded, it could not be expected to be a definite compound. In the case of the other two analyses, however, both made on crystalline material of approximate purity, the results are quite accordant and agree with a compound of the general formula R_6S. The ratio of the metals is, roughly, two of iron to one of nickel and copper, and it will be seen, from the theo-

* *American Journal of Science*, vol. 49, p. 365, On Two Peculiar Products in the Nickel Manufacture.

retical composition which I have calculated on that assumption, that the results of analysis do not vary very much from those calculated.

From a chemical standpoint this compound is of great interest, as it distinctly illustrates the hexatomic character of sulphur, and to the best of my belief is the only known sulphide of similar composition. The manner of occurrence is in small cubical crystals, forming fern-like aggregations, in the cavities in the concretions in the furnace-hearth.

I think it is quite probable that analogous compounds will be formed in copper-smelting; and I would be pleased to receive samples of any similar product from any one whose attention may be directed to this note.—J. B. MACKINTOSH, *Trans. of Amer. Inst. of Min. Engineers.*

The Seasoning of Lumber.

In a report presented at the Master Car Builders' Convention, recently held in Minneapolis, on the "Standard Sizes of Lumber for Freight Cars," occurs the following: "It is possible to specify a certain maximum amount of moisture in car lumber, and to obtain lumber to such specification by measuring the amount of moisture in sample borings.

"The borings from about a cubic foot of wood are placed in a phial and weighed on a chemist's balance; they are then evaporated to dryness and weighed again, the per cent. of loss noted representing the water driven off.

"In this way the fluctuation of moisture during the process of seasoning has been obtained for oak, ash, and pine, and it is shown in the diagram which accompanies this report.

"Green oak, as received in the yards, contains 45 to 50 per cent. water, and after a year's seasoning, it still contains over 30 per cent. Norway pine from the mills contains over 25 cent. water, and a year's seasoning reduces it to 10 or 12 per cent.

"Pine should be seasoned at least one year, and oak two years, to avoid excessive shrinkage and early decay.

"The amount of water in lumber may be taken as a direct measure of the length of time it has seasoned."—*The Railroad and Engineering Journal.*

Mr. Henry Adams, M.I.C.E., at a meeting of the Civil and Mechanical Engineers' Society, London, read a paper on "The use and care of chains for lifting and hauling," in which, among other formulæ, these were given: d being diameter of the iron in ⅛ths of an inch; breaking weight in tons for short-linked crane chain $= \frac{1}{2}d^2$; admiralty proof strains in tons $= \frac{3}{16}d^2$; safe load for ordinary cranes in *cwts.* $= 1\frac{1}{2}d^2$; safe load for coal cranes in *cwts.* $= 1\frac{1}{4}d^2$; weight in pounds per fathom $= d^2$.

The proof test is made upon lengths of 15 fathoms each; the breaking test upon 4 foot lengths.—*American Engineer.*

Oscillations in Lake Michigan at Chicago.

The wind and barometric pressure produce a constant oscillation of the surface, and at times a swinging motion from shore to shore. One

oscillation or swing across the lake, as shown by the automatic gauge placed at the mouth of the Chicago River, lasted about twenty minutes. The greatest oscillation was over two feet. The oscillations are relatively greatest at the south end of the lake. . . . It is found that the wind is the prime factor in moving the water, and that the currents are generally in the direction of the wind. During a prolonged gale from the north, it happens that perhaps the entire surface moves southerly, with the bottom current returning to the north. If the wind should change to the west, the surface-current will then turn to about northeast, forming a resultant between the wind and the bottom current until equilibrium takes place. West winds usually lower Lake Michigan and raise Lake Huron several inches, and east winds *vice versa*, causing strong currents in the Mackinaw Straits during the time. The motion of the water in the lake opposite Chicago is sometimes not inconsiderable. Currents of one to two feet per second are common.—*Rudolph Hering—"Paper on Drainage and Water-Supply of Chicago," in Proceedings of the Engineers' Club of Philadelphia.* **

BOOK REVIEWS.

THE METALLURGY OF SILVER, GOLD AND MERCURY IN THE UNITED STATES. In two volumes. By Thomas Egleston, LL.D., Professor of Mineralogy and Metallurgy at the School of Mines, New York City. Vol. I. 558 pp. Large octavo. John Wiley & Sons. New York. Engineering. London.

For some years Professor Egleston has been engaged in preparing his various notes, memoirs and monographs on metallurgical subjects for publication in permanent form. Two volumes are to be devoted to Silver, Gold and Mercury, and it is expected that others on Copper and Lead, are to follow.

The first volume of the series has just been published, and is upon silver. The professor discusses, in detail, the various processes and apparatus used in the metallurgy of silver in this country, first devoting some sixty pages to a history of the progress of metallurgy in the United States since the discoveries of gold in California, and copper at Lake Superior.

The Western gold and silver ores are divided by the author into four classes:

1. "Those which contain copper enough to be smelted for copper, from which the gold and silver are extracted in the wet way."

2. "Those in which there is a large quantity of lead, which can be smelted for lead, and the gold and silver extracted from it."

3. "Ores in which there is neither copper nor lead enough to allow of a process of smelting, but which can be treated in pans."

4. "Ores which do not contain enough of either lead or copper for smelting, which are poor both in silver and gold, contain large amount of sulphur, arsenic and antimony, and can only be treated by leaching."

After describing various methods of sampling, a chapter is devoted to each of the following subjects:

Zinc Desilverization.
Separation of Gold and Silver from Copper.
Crushing Machinery.
Roasting.
Patio and Cazo Amalgamation.
Barrel Amalgamation.
Pan Amalgamation.
Treatment of Silver Tailings.
Leaching Processes.

Written largely from the professor's notes taken at the various works, and illustrated throughout with working drawings, the volume is a very valuable addition to metallurgical literature. It is handsomely printed, with clear type and good margins.

The volume on Copper and Lead will include the extraction of silver and gold from these metals.

ANALYTICAL MECHANICS. Professor W. G. Peck. New York and Chicago: A. S. Barnes & Co. 1887.

In this work Professor Peck has reconstructed his elementary treatise on mechanics, introducing matter which has heretofore been given by lectures to the students of the School of Mines. The differential and integral Calculus has been largely used.

The fundamental principles of the science are, for the most part, based on the axiomatic laws of Newton; but the more modern ideas of work and energy have been carefully considered and incorporated in the text. Goupilliere's elegant method of treating the resistance of friction has been fully illustrated in the processes of finding the moduli of the elements of mechanism.

In reading the book, we find many improvements introduced in the discussions: for example, in the demonstration of the principle of moments, in the discussion of parallel forces, in the theorem of work, in the chapter on Work, Energy, and Impact.

The author, in this book, does not treat very fully of the mechanics of liquids and gases, but gives enough for a general engineering course.

J. K. R.

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THE FUTURE OF GOLD AND SILVER.

BY J. S. NEWBERRY.

GOLD and silver are called the precious metals not because they are more useful to man than all others, for it might be easily shown that iron in its different phases has been a far moae important factor in the progress of civilization and more precious in the sense of utility. Nor is it simply because these metals are more rare than others that they are so highly prized, since platinum, iridium, vanadium, and many others are less abundant. What, then, has caused gold and silver to be so greatly esteemed? *Simply because they have been chosen as media of exchange and representatives of value.* Some circulating medium becomes a necessity with every people emerging from barbarism, as their commercial transactions become too considerable to be effected by barter alone. Even among savages a kind of currency is used, as cowries by the African tribes and wampum by the North American Indians.

Gold and silver have been selected as circulating media because they possess special and unique qualities which fit them for this use.

1. They are generally distributed over the earth's surface, so that no one nation can monopolize them, and yet so sparsely that they cannot be produced in such quantity as to lose their value.

2. They are nearly indestructible, being uninjured when passed through fire or water.

3. They are capable of being coined, *i. e.*, of being divided with exactness into pieces on which a legend expressing origin, weight, and value may be indelibly inscribed. These qualities caused them, many thousands of years ago, to be chosen and retained for the great use they now serve. The oldest records of the use of gold and silver show that they were employed as circulating media, and that their relative values had already been established. An inscription in the Temple of Karnak, of the date of 1600 B.C., mentions gold and silver as materials in which tribute was paid, and we read in the Bible that Abraham (1500 B.C.) "weighed to Ephron, the Hittite, four hundred shekels of silver, current money with the merchant," for the purchase of a burial place for his wife.

Both of the precious metals were, however, used for ornamental purposes long anterior to these dates, as we find gold and silver ornaments among the relics of the Bronze Age of the Prehistoric Era.

It is true that at the present day in civilized countries all considerable transactions of commerce are effected by checks, drafts, bankbills, etc., *i. e.*, a paper currency, and it is seriously urged by many that, since the value of each is conventional, it would be much better to substitute paper backed by the pledged faith of a nation, for gold and silver, which are obtained with so much labor and often with so much moral degradation. But the experience of the world has proved beyond argument that the power to create "fiat" money cannot be safely entrusted to any government, whether it be despotic or democratic. That power always has and always will be abused, and there is no safe basis for national or individual finance but the precious metals, which cannot be created at will and to the production of which nature has placed a limit, since it bears a tolerably constant ratio to human labor. The only reason why national securities or private commercial paper have recognized value and serve as circulating media is that each is, or is supposed to be a certificate of deposit, and that somewhere a dollar in silver or gold is accessible for the redemption of every dollar in paper.

Since then the experience of the world has proved that nothing else is so well adapted as silver and gold to become representatives of value and circulating media, and these metals are accepted in all

countries as having in themselves a value that is, within moderate limits, invariable, and thus practically intrinsic, there is no probability, we may even say no possibility, that they will cease to be what they now are, the basis of all financial systems and, directly or indirectly, the media of all commercial transactions.

In the foregoing remarks the two metals, gold and silver, have both been designated as precious and as equally indispensable in the economy of civilization; and so they are, for the reason that they have equally important and, to some extent, interdependent functions. Gold, as the less abundant, has a higher value; an ounce of the more precious metal having been worth, at different times and places in the 3500 years during which accurate records have been kept, from ten to twenty ounces in silver; the ratio having remained with remarkable constancy through hundreds of years, at about fifteen to one. Of late years a decrease in the production of gold, an increase in that of silver, and more especially the demonetization of silver by Germany, and the limitation of silver coinage by the Latin Union, have disturbed the relation between gold and silver and have somewhat depreciated the latter metal. This has produced much heated discussion, some unwise legislation, and has divided the financial world into two parties—the monometallists, who would have gold the only standard of value, and the bimetallists, who favor a double standard, gold and silver. Most of the clamor to which this question has given rise has been due to ignorance, the designs of those who deal in money—who want it dear and who make their profit from their commissions in harmonizing financial discord—or of those who have had silver to sell and have naturally tried to bull it in the market. If the truth were known and clearly seen, every right-minded and intelligent man would be a bimetallist so far as this, that he would accept as inevitable the concurrent use of gold and silver as circulating media, and would approve a periodical or occasional adjustment of the ratio between them. Silver is now used by all nations as currency, and by two-thirds of the civilized population of the globe as the only standard of value. It is therefore evident that it is hopeless to expect it to be abandoned or seriously crippled as a medium of commercial exchange.*

* The countries which use gold only as a standard of value are Great Britain, Denmark, Sweden, Norway, Portugal, Turkey, Canada, Brazil, Argentine Republic, Persia, Cape of Good Hope, and the Australian Colonies, with an aggregate population of 138,-

There is another influence, also, stronger than legislation, or individual prejudices or preferences, an influence which will maintain the use of silver as currency—will make it money in fact—for all time in all countries, will make it work side by side with gold, will compel an adjustment of their values and thus make standards of both, and this influence is the peculiar and unique fitness of silver for subsidiary coinage. It here supplies a want which is radical and that nothing else, not even gold, can supply.

We say gold is worth twenty dollars an ounce troy, and as one of these dollars is the average equivalent of a day's labor of a man, the true financial unit, we see that gold by no means satisfies all the requirements of a circulating medium. The gold dollar is a thin scale of metal no larger than one's finger nail, a coin too small for convenient and safe use. But the laborer must divide the dollar which pays his day's work into many fractions to meet his multifarious wants. It will not do to offer him a scrap of paper representing a fraction of a dollar; this, in constant wear, passing from hand to hand, is soon frayed, torn, spoiled; fire burns it, water reduces it to a pulp; he will have none of it.

Silver, however, just meets this want, for, like gold, it is almost indestructible, attractive to the eye, pleasant to handle, easily coined; and so it is divided into dollars, half dollars, quarters, and dimes. These serve most of the purposes of a subsidiary coinage, but not all. The half-dime formerly issued from the mint was too small and the star three-cent piece was an abomination; now both are practically unused, the larger "nickel" taking the place of the half-dime. We have here practically reached the limit of division in the coinage of silver, and yet there are minor transactions in everyday life that cannot be expressed by dimes or even nickels, and so society has been compelled to resort to a cheaper metal, from which it has coined its pennies, farthings, cents, and centimes. For these copper is usually employed, but any metal or alloy not too dear and adapted to coinage would serve, for the value of the material is so low that there is no danger of counterfeiting.

000,000. Those which use silver only as a standard of value are Russia, Austria, Mexico, Central America, Ecuador, Peru, China, British India, Siam, Burmah, Dutch Colonies of Java, Madura, Egypt, Tunis, and Tripoli, with an aggregate population of 772,000,000. Those using both gold and silver and having the double standard are France, Belgium, Switzerland, Italy, Greece, Roumania, Holland, Spain, United States, Colombia, Venezuela, Chili, Uruguay, Paraguay, Bolivia, Cuba, and Algiers, with an aggregate population of 181,000,000.

I have attempted to show in the foregoing paragraphs that three metals are needed to form a metallic currency such as is, and will always be, used by every civilized or semi-civilized people. Each of these metals holds a distinct place in the scale of rarity and value, and is indispensable for the various transactions of commerce in everyday life, from the dinner at Delmonico's, for which the swell pays a double eagle, to the purchase of a potato or cabbage leaf by the French pauper for a centime.

There is also another and not less important purpose served by the precious metals in the financial operations of civilized nations, and that is to form a deposit for the redemption of bonds, drafts, and checks which, for convenience, are now so largely substituted for the metallic currency that was formerly the sole medium of exchange. For this purpose the metal need not always be coined, for while it is necessary for financial safety that every piece of commercial paper should have behind it a metallic basis which can serve for its redemption on demand, it would be quite as well if much of the great hoards of gold and silver in our own and other national treasuries were in the form of large ingots. These, if of ascertained weight and fineness and stamped with their value, would be more easily counted than coin and be less readily purloined, and their use would save a considerable portion of the expenses of coinage.

Gold and Silver in the Past.

The history of the production of the precious metals in different ages and the changes in their absolute and relative values includes some surprising and almost incomprehensible facts.

Chevalier, Jacobs, Danson, etc., estimate the whole amount of gold and silver possessed by the nations of Europe at the discovery of America to have been less than $200,000,000. From that time to the beginning of the present century there were added to the wealth of the world, according to the same authorities, from the mines of America, in silver, $4,152,650,000, and in gold, $1,415,544,000. By this increase of capital the purchasing power of money was greatly reduced, but the increase of silver, three times as great as that of gold, changed their relative values from 11 to 1 to 15 to 1. This we may designate as the *first age of silver*, which reached to 1848, during which the production of gold in the world was about $3,200,000,000, and that of silver $6,200,000,000, while

the ratio of value remained unchanged. In 1848 began the *age of gold*, which continued to 1872, and during which, chiefly from Russia, Australia, New Zealand, and California, the production of gold was $2,665,675,000, and that of silver, $1,105,200,000, and yet the relative values of gold and silver remained practically unaffected, though much alarm was felt lest gold should lose its value, and precisely the same things were said of it as now are said about silver.

From 1873 to 1886 ensued another silver period, in which the production of gold was $1,298,605,024, and of silver, $1,353,287,349. The ratio of value fluctuated from 15.63 to 20 to 1. The production in 1886 was gold, $97,761,000; silver, $130,383,000.*

The amount of metallic money in the world in the year 1848 is estimated by the director of the mint to have been gold, $2,000,000,000; silver, $2,900,000,000. And the amount in 1872 is estimated by the same authority to have been gold, $3,750,000,000; silver, $3,250,000,000.

The money in circulation among the twenty-four wealthiest nations, having a population of 446,669,890, is estimated by the director of the mint, in 1880, to have been $7,116,327,786, viz.: paper, $3,306,480,151; gold, $2,685,691,373; and silver, $1,124,156,263.

The consumption of gold and silver in the arts was, in 1886, according to Dr. Kimball, gold, $48,745,884, and of silver, $21,676,702.

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* The relative values of the precious metals in different ages have been as follows:

1600 B.C. Karnak, Egypt,	13.33 to 1
708 " Khorzabad, Assyria,	13.33 to 1
440 " Time of Herodotus,	13 to 1
Birth of Christ, Rome,	12 to 1
300 A.D. Rome,	14.40 to 1
800 " France,	12 to 1
1250 " Genoa and Venice,	10.5 to 1
1500 " Spain and Germany,	11 to 1
1600 " Europe and America,	12 to 1
1650 " " " "	13 to 1
1700 " " " "	15 to 1
1800 " " " "	15.20 to 1
1800–1872 A.D. Europe and America,	15.50 to 1
1876, July (maximum),	20.17 to 1

THE FUTURE OF GOLD.

Probably nine-tenths of all the gold obtained by man has been taken from placer deposits, and our American experience has been no exception to the general rule. Previous to 1847 our total gold production amounted to $12,000,000, but between 1847 and 1887 about $1,750,000,000 were contributed to our stock of gold. Of this, nearly three-fourths came from placer deposits. In 1850–56 we obtained more than $50,000,000 per annum in gold from the placers of California, and almost nothing from gold-bearing veins. Now, with an annual production of $30,000,000, about one-half only is from placers. Our own territory has been so thoroughly explored that no considerable superficial deposits of gold are likely to be discovered, and nearly the same thing can be said of the entire world.

In the northern extension of our Western mountain ranges in British Columbia and Alaska there are probably important deposits of gold. These mountains are everywhere auriferous within our territory. In Alaska gold mines are successfully worked in a few localities, and gold is reported from many others. Dr. George M. Dawson has also found indications of gold for five hundred miles along the mountains north of Frazer's River. Hence we may hope that a considerable contribution will be made by Northwestern America to the gold product of the world. It is likely, however, to come from this region in a moderate but perhaps perennial stream, and not in a flood. Great difficulty will attend the working of mines, and especially placer deposits, in the mountains of Canada and Alaska. The winter is long and terribly severe and the snowfall heavy, limiting active operations to three or four months in the year; the surface is very much broken, entirely unproductive, covered with a dense forest, and peopled by unfriendly Indians. All supplies must be imported by long, rough, and expensive routes. These difficulties will restrict the production of gold to such a degree that unless the mines and placers should prove to be rich beyond all present indications, the gold product of this region must have a good and not a bad influence on the finances of the world.

Eastern North America contains, in the Alleghany belt, a vast quantity of gold, but this is generally in the form of low-grade, pyritous ores, difficult to treat. With skill, energy, and economy

they may, however, be worked at a profit, and we may look upon them as offering a handsome reward for the exercise of these cardinal business virtues, and as promising to supply a not strong but steady stream of this financial vital fluid.

Mexico has no important deposits of gold. For three hundred years her territory has been explored and her mines worked by an industrious and avid race of miners, who would certainly have discovered and unearthed any considerable golden treasure. In a few localities gold veins and surface deposits are worked, but the relative quantity of this metal is everywhere small and the rainfall has been in the past too slight to furnish the motive power for extensive erosion, as it is at present insufficient to supply the needed water for successful gold washing. When no revolutions have interfered with the production of precious metals in that country, Mexico has steadily yielded about $1,000,000 per annum in gold. This contribution may be kept up for many years, but can hardly be exceeded.

The west coast of South America, so rich in silver, is, like Mexico, poor in gold. The superficial deposits which formerly existed here and there were diligently worked and practically exhausted by the Incarial population. We learn from the Spanish chronicles that a very large sum was realized by the invaders from the golden decorations of the Temple of the Sun at Cuzco, and that many of the vessels with which the prison chamber of the unfortunate Atahualpa was filled were composed of gold, but since that time the gold product of the whole coast from Equador to Chili has been insignificant. The mines which subsequently poured hundreds and even thousands of millions into the Spanish treasury, yielded only silver.

Colombia, Venezuela and Brazil have, on the contrary, always been producers of gold. It is estimated that from Brazil alone more than $1,000,000,000 in gold were obtained during the first three hundred years after the advent of the Portuguese. Colombia and Venezuela are now yielding about $4,000,000 each annually, but the great Callao mine which furnished one-third of this sum has of late greatly fallen off in its productiveness. The superficial gold mines of this portion of South America were diligently worked by the ancient inhabitants, and they probably secured the greater part of the gold they contained. The gold images which they buried with their dead are now sought by a special class of

miners, if such they may be called, who exploit the old cemeteries with considerable success, and gold washing is carried on in many localities. But these gold fields are no longer virgin ground, and we cannot expect them in the future to yield more gold than they do at present.

The gold production of Australia has been but little inferior to that of our own country. At first it was exclusively from the placer deposits, and when the richest of these were worked out the yield was greatly reduced. It has, however, been revived by the development of reef-mining, and the annual yield from both sources is now about $30,000,000. We may hope, too, that the present rate of production will be maintained or approached for many years to come.

The great Asiatic continent once had its famous gold mines like Australia and America, but it has been so long occupied by a dense human population that its stores of gold have apparently for the most part been exhausted. The Chinese, the Hindoos, the Tartars and their ancestors, who so long occupied the interior of Asia, have all been diligent gold hunters, and they have left no stone unturned beneath which this, the first found and most highly prized of metals, could be concealed. From the continent of Asia and its dependencies, we may then expect little more than the present modest contribution, which may reach four or five millions of dollars per annum.

The gold product of Europe is now perhaps $30,000,000 a year; of this nearly all or about $25,000,000 comes from the Ural Mountains. The gold mines here came under the control of the Russian government in 1820, since when a steady stream, an average of over $20,000,000 per annum, has flowed from them into the treasuries of the world. How long this contribution may continue we cannot say, but it is scarcely likely to change much for some years to come.

It is possible that important discoveries of gold may be made in as yet unknown gold veins and placers in Africa, but the latter is highly improbable. The placers of Ethiopia, as we learn from the Egyptian records, were worked as early as sixteen hundred years before Christ, and we have reason to believe that the surface deposits of that continent, as well as those of Asia, were mostly exhausted before the Christian era. The working of mineral veins has hardly been attempted by the barbarous native population of

Africa, and it is quite possible that stores of gold deeply buried in the earth, beyond the reach of savages, but destined to be exploited with the advance of civilization, will form an important factor in the future history of gold. The "golden sands" which have become inseparably connected with our ideas of "the dark continent" must lead up to sources in gold-bearing veins which, in the future, and for centuries may help to keep up the world's needed supply of gold.

With these facts in view we need not expect any other such floods of gold as those that inundated the markets of the world from the placers of California, Australia, and New Zealand, but the present annual yield, about $100,000,000, is likely to be maintained for some years. Individual mines have but a limited term of service, and it is not probable that many gold mines like the Comstock and the Callao remain to be discovered. Hence placers and great mines are not likely to be disturbing elements in the gold market, but the more thorough exploration of different countries will bring to light more productive ground. Railroads and other channels of travel and traffic, and improved processes for treating refractory and low-grade ores, will bring within reach and render productive thousands of minor gold deposits, which will go to maintain the aggregate production. The world's stock of gold will gradually decline from the diminished supply, the increased consumption in the arts, the abrasion of coin, etc., but this change must take place slowly, and inventions like that of Cowles's Electric Process in Metallurgy may give us substitutes for gold of equal value in the arts.

The Future of Silver.

The problems of the future in silver production seem all to lie within our own country. The great silver belt of the world crosses our territory from British Columbia to Mexico, and stretches thence southward to Chili. It is interrupted only at the Isthmus, where it is submerged. From this belt more than $6,000,000,000 have been taken since the discovery of America, and here we must look for the signs of promise in the future production of silver. As I have before said, within our territory the silver product is not likely to increase, but is almost certain to decline, though perhaps slowly; and we may expect our mines to yield $40,000,000 to $45,000,000 per annum for many years to come.

Mexico has continued for half a century to produce annually $25,000,000 in silver to $1,000,000 in gold. There are no indications that this state of things will soon change. It has been predicted that, with the introduction of foreign capital and improved machinery, the production of the Mexican mines would be greatly increased, but the experience of the last five years has not confirmed such predictions. The Mexicans are experienced miners, skilled in producing great results by simple means, are frugal, peaceful and industrious, and it is very doubtful whether the extravagant, impatient and speculative Yankee, with all his improved methods and machinery, will often succeed where the patient, close-working and economical Mexican has failed. No one knows a good thing when he sees it better than a Mexican miner, and none is less likely to relax his hold when once he has his grip upon it. I think it will be rarely found that a mine abandoned by the Mexicans is worth working, and I am quite sure that we are not to have any considerable increase in the silver production of Mexico.

The silver mines of Peru and Boliva (Cerro de Pasco and Potosi) are the most famous in the world. No one knows exactly how much silver was taken out of them, but Chevalier estimates it at $2,492,426,880. They have produced comparatively little for many years, but it has been generally believed that when the railroads, commenced by Henry Meigs, should be carried into the countries where the mines are situated, and modern skill, capital and machinery be brought to bear upon them, they would still yield incalculable sums. All this is, however, a figment of the imagination. Recent thorough explorations by American experts, continued through two years and aided by the diamond drill, have failed to discover any bonanzas in either of these mines. Low-grade ore there is in plenty and that which may perhaps be worked with a small margin of profit, but as disturbers of the public peace in the financial world, the South American silver mines need not be feared. In the last report of the Director of the Mint the yield of the silver mines of Bolivia is estimated at $16,000,000 per annum, but I am led to believe that it is much less, probably not half of this amount. Chili is now producing about $6,000,000 in silver per annum, and it is scarcely probable that this sum will ever be greatly exceeded. The mines of Copiapo have certainly seen their

best days, and those of Caracoles, more lately discovered, will never rival these in productiveness.

The silver production of America is about three-fourths of that of the whole world, and the sources of silver elsewhere are so widely scattered and individually so unimportant that they can have little bearing on the future history of this metal. From America, then, if from anywhere, must come the overwhelming flood of silver which, in the minds of some persons, threatens disturbance and disaster in the financial world. After a careful survey of the field, however, I see no indications of any future glut in the silver market. The mines of Mexico and South America have been worked for three hundred years by those who possessed skill, energy, and economy; and they have taken from them, year by year, about all they were capable of yielding. Whoever comes after them will find that they have skimmed the cream of all the known ore deposits, and have been so thorough in their explorations that there is little chance of the discovery of others from which sums can be realized that can disturb the money market.

It should be remembered that these countries are easy of exploration, are mostly without timber, and are traversed by mountain ranges, of which the details of structure are everywhere visible. I think, then, that I am quite safe in saying that no danger of financial disturbance need be apprehended from the silver mines of Mexico or South America.

Whichever way we look, therefore, we fail to perceive any indication of storms in the business world such as might be occasioned by great changes in the production of either of the precious metals; certainly no threatenings of a sudden or serious increase in the annual yield of either. On the contrary, a different and much more formidable danger is to be feared; viz., a gradual exhaustion of our mines and the diminution of the stock of gold and silver now on hand below the point where they best serve the world's purposes. Indestructible, uncreatable, readily divisible, easily coined, widely distributed, but nowhere abundant, they have been proved by long experience unique in their adaptation to the wants of society as representatives of value and circulating media. They are equally necessary and both indispensable to the safe and easy transaction of the commerce of the world. It would be a great misfortune, therefore, if either should be produced in such redundance or deficiency as to seriously disturb the relations

which they have sustained to each other and to man's daily labor, which is the real unit of value.

I am happy to say that with my lights I can perceive no indications that either of these dangers is imminent.

ON THE THEORIES OF THE LATERAL PRESSURE OF SAND AGAINST RETAINING WALLS.*

BY MANSFIELD MERRIMAN.

THE various theories and formulas which have been presented for the lateral pressure of sand are all more or less defective and contradictory, either in the fundamental hypotheses upon which they are based, or in their application to limiting cases. It is attempted in this paper to point out that these defects are due to the fact that the theories assume properties of sand which are not actually true, and that correct formulas can only be established by determining experimentally the laws that govern the direction and intensity of the pressure.

The word sand implies a collection of particles devoid of cohesion, inelastic, homogeneous, and possessing an angle of natural slope. It is further supposed, if a mass of this material be sustained by a wall, that along a certain plane, called the plane of rupture, the condition of equilibrium or incipient motion exists. All theories are based upon these definitions, which in general may be regarded as a satisfactory basis or point of departure.

These definitions, however, are not sufficient to determine the direction and intensity of the lateral pressure of a bank of sand against a wall, since in connection with the conditions of static equilibrium they do not furnish a sufficient number of equations to determine the unknown quantities. Hence some further assumption is necessary, and usually this is made in regard to the direction of the pressure, and different assumptions give rise to different theories and formulas.

The oldest rational theory—that of Coulomb—assumes that the resultant lateral pressure is normal to the back of the wall. Then

* Read before the American Association for the Advancement of Science, August 15th, 1887.

a prism of sand, included between the plane of rupture and the back of the wall, acts by virtue of its weight against these two surfaces in known directions, and the intensity of the maximum thrust is found without difficulty. The results of this theory are practically as satisfactory as those of later authors, but a theoretic discrepancy exists which indicates that the fundamental assumption is incorrect. Thus, the point of application of the pressure on the wall is found to be at two-thirds of its height from the top, but this in connection with the other conditions brings the point of application of the thrust against the plane of rupture at a different position, except for the special case of a vertical wall. Now whatever is true regarding the point of application of the thrust on one surface must be true for the other, and hence the results of this theory are logically contradictory.

The common theory—that of Poucelet—assumes that the lateral pressure against the wall deviates from the normal by an angle equal to the angle of friction, or angle of natural slope of the sand. Here the same contradiction exists as in the older theory, and to even a greater degree. Other discrepancies are also found to arise, such, for instance, that if a wall be horizontal the pressure upon it is not vertical. On the whole, the fundamental assumption of this theory is less satisfactory than that of the older method.

A late theory, due to Weyrauch, makes no assumption regarding the direction of the pressure against the wall. Starting with the hypothesis that the points of application of the pressures on the wall and plane of rupture must be at the same relative positions (namely, at two-thirds of the length from the top), the conditions of equilibrium serve to determine the direction and intensity of the pressure against the wall. This direction is found to vary with the inclination of the wall, being normal when the wall is vertical, and deviating from the normal as the wall inclines from the vertical. The contradictions of the older theories are thus avoided, but a new and more serious difficulty arises. Evidently the lateral pressure should decrease as a wall is inclined backward and should become zero when the wall has an inclination equal to that of the natural slope of the sand. The formulas of Weyrauch, however, make the resultant pressure increase with backward inclination, so that a bank of sand inclined at the angle of repose exerts a very large lateral pressure, and hence would require a wall to sustain it. This result is not only theoretically incorrect, but in practice would lead to

such absurd constructions as to wholly forbid the use of the formulas for backward inclined walls.

The determination of the lateral pressure by the theory of internal stress in an unlimited mass of sand is a method followed by Rankine, Winckler, and others. This theory perhaps gives the correct pressure against an ideal plane in an unlimited mass, but it cannot be the same as the pressure against a wall except for special cases, for the values are in general the same as those found by the formulas of Weyrauch, and for backward inclined walls lead to the same incorrect results.

Thus, all theories are defective and contradictory either in fundamental hypotheses or in the final practical formulas.

The fact that these contradictions exist indicates that the definitions or hypotheses at the bases of the theories are incorrect. The definition requiring that the surface of rupture shall be a plane may be objected to, but the objections are slight compared to those which can be made against either of the hypotheses. A careful consideration of these seems to lead to the conclusion that the point of application of the resultant lateral pressure is not in general at the position usually assigned, namely, at two-thirds of the height of the wall from the top. The reasoning by which this position is determined is briefly the following: the total pressure varies directly as the square of the height, hence the unit-pressure at any depth below the surface varies directly as the depth, and therefore the point of application must be as stated,—the whole law of distribution of the pressures being the same as for water. To this reasoning there seems at first no objection and none appears to have been heretofore hinted at, yet, if this be true for a material like sand, would it not also be true for a solid mass included between a wall and a plane of rupture? Evidently not; and hence it should not be taken as established that the unit-pressure varies directly as the depth because the total pressure varies as the square of the depth.

For the case of water there is no ambiguity, since the pressure is known by experience to vary directly as the depth and to be normal to any retaining surface. Hence it follows that the total pressure varies as the square of the depth, and that its point of application is at two-thirds the height of the wall below the water surface.

To render the theory of the lateral pressure of sand as perfect

as that of water it is necessary to determine by experiment sufficient data regarding the direction of the pressure or the law of distribution of the unit-pressures, so that hypotheses may not be needed as the basis of theoretical investigation. When these data have been found we shall have a definition of the word sand, which, in connection with statical principles, will enable formulas for its lateral pressure to be established that shall be free from defects and contradictions.

Practically the formulas of any theory are sufficiently precise for the design of retaining walls. As a rule, walls are nearly vertical, and for the pressure against a vertical wall the different theories give results which do not greatly differ. The variation of the material behind the wall, due to rain, frost, shocks and jars, cannot of course be theoretically estimated, but must be provided for by a factor of security. Even if a satisfactory theory of the lateral pressure of earth were deduced, it is not probable that it would be more advantageous in practice than those now in use. Yet it would be an advance in science if the perfect definition for sand and the true theory of its lateral pressure could be established.

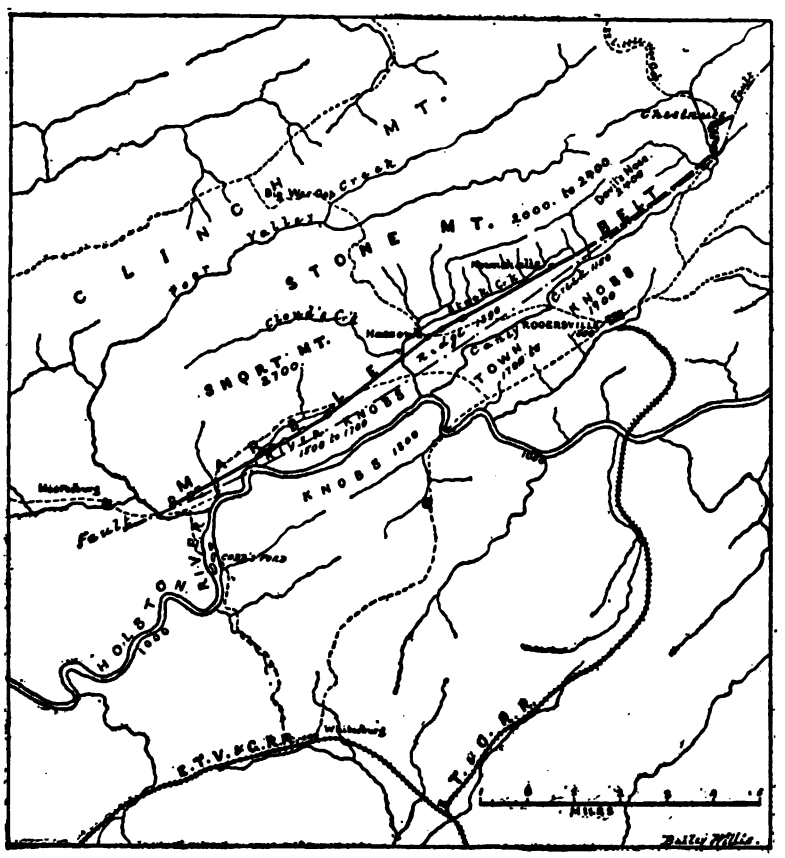
THE MARBLE OF HAWKINS COUNTY, TENNESSEE.

BY BAILEY WILLIS.

SOME years ago, when the location of the East Tennessee, Virginia and Georgia Railroad was under consideration, the citizens of Hawkins county, Tenn., were called upon to vote for or against a subsidy to the road, and they expressed their dislike to all such innovations by a strong adverse majority. As some of their neighbors in the back valleys of Hancock county still put it: "We don't want no railroad a comin' through hiar ter tote off all the craps."

The voice of conservatism was obeyed, the railroad went elsewhere, and Rogersville, the county seat and formerly an important point on the stage line from Abingdon to Knoxville, was isolated. With isolation came stagnation until connection with the main line was established by a branch built after many years, and the Rogersvillians became tributary to the world of monopolies they

had sought to shun. And, as if to confirm their early fears, the branch line passed into the hands of a private gentleman, who might pocket, if not "all the craps," at least a large part of their value. That he does not do so is due to that wise liberality by which capital attracts profitable business where it might extort tribute.



Marble Belt, Hawkins Co., Tenn.

The construction of the Rogersville Railroad was prompted no doubt in part by the fact that the place is the point of convergence of two pike roads, which cross Clinch Mountain at Big War and Little War Gaps and concentrate the product of an extensive farming and timber producing region, but another important factor must have entered into the calculation of freight

supply, namely, the marble quarried from the belt which, at its nearest point, is two miles northwest of the town.

Approaching Rogersville by rail the Holston river is crossed on a high bridge, the round hills of a Silurian limestone area are passed by a heavy grade, and the train slips down into the small valley, where Mr. Rogers, great grandfather of the present generation, placed his village. Northwestward, behind the court house spire and gilt dome of the masonic temple, the "Town Knobs" rise to a sharp crest, and beyond a bold descent of 800 feet lies the broader valley of Caney creek. The two valleys and the intervening ridge are cut from Cambrian strata, which extend to the further slope beyond Caney creek. There one may span with one hand the breccia between a dark Cambrian and white Trenton limestone, strata separated by twelve thousand feet of rock when originally deposited, but here brought in contact by a fault; the hade of this fault is not far from 35° under the upthrow and the displacement on its plane may be roughly estimated at five miles. Its strike is in a general way northeast and southwest, parallel to that of the Cambrian beds and to the ridge which they determine.

On the northwest side of this fault a strip of Trenton and Nashville rocks extends for a distance of sixteen or seventeen miles, and is cut out at either end by the displacement; lying in and coextensive with them is the bed which yields merchantable marble. It is a stratum of highly ferruginous earthy limestone, generally crystalline, but sometimes shaly, which overlies the Maclurea limestone of Safford and underlies the calcareous shales of the Nashville group. It is difficult to state the thickness of the marble-bearing bed, for it has no well defined upper limit, but it is probably safe to say that it does not exceed 300 feet.

The outcrop of this horizon has been called by Safford the "Red Belt";* it appears at the surface on several extended lines and contains marble throughout its length, but the chocolate colored variety is found only in the limited area within Hawkins county. It is one of the unanswered questions whether this color is due wholly to the conditions of sedimentation when the beds were forming flat on the floor of the Silurian sea, or to subsequent changes in the degree of oxidation and hydration of the

* Safford, Geology of Tennessee, p. 238.

iron accompanied by crystallization of the carbonate of lime Quite certain it is that no fiery furnace need be imagined to. account for such effects, and that the iron may have been deposited as carbonate or hydrate, and have passed to the condition of hematite by slow chemical alteration, even in the presence of abundant moisture.

Instances of this kind are not uncommon. Thus on Block Island, thirty miles out in the Atlantic, ferruginous nodules contained in the Cretaceous clays are of a decided yellow color as long as they are protected from the atmosphere, but turn to a bright red when exposed on the beach to fog and spray, and when they are broken open the dehydration is seen to extend from the surface inwards to a larger or smaller core of limonite, according as the nodule is large or small and in proportion to the duration of exposure.

Or I may cite the curious changes of color in the frescos of the old church of Kappel in Canton Zürich, Switzerland, which were observed and described as far back as 1854.* There, probably in the 13th century, one of the Gesslers built a chapel wherein the bones of successive generations of turbulent knights might rest, and he adorned the walls and arched ceiling with frequent repetitions of their coat of arms—a triangular shield, tilted, which supported on the upper corner a helmet surmounted by a parrot's head and black plume. Shield and helmet were blue except for a white visor and the parrot was also blue with a white bill.

This symbol was painted with azurite, the hydrous carbonate of copper, on a dark brown background, for which limonite was the coloring matter. In the course of centuries moisture penetrating the old church wall has in many places slowly substituted a molecule of water for one of carbonic acid in the copper paint; slight change, to be sure, but a Gessler would no doubt challenge to mortal combat a knight bearing the shield as it now appears on the chapel roof. The Gessler fought under an emblem of azure blue; he sleeps beneath shields and parrots of malachite green. And here in the presence of moisture chemically active and capable of entering into combination in the copper carbonate, the limonite of the background has given up its combined water, and glowing

* Volger, G. H. Otto, Studien zur Entwickelungsgeschichte der Mineralien.

red surrounds the brilliant green where brown once set out the bright blue shield.

Were it not proven by many such facts as these that even atmospheric influences are sufficient to chemically alter and crystallize rocks, the metamorphosed condition of the marbles might be attributed to the force which has upheaved and faulted them. The action of such force is apparent in their present position as compared with the horizontal bedding of the original deposit.

The slightly curved fault, of which the marble belt is the chord, was produced by a compression strain that broke through twelve thousand feet of rock, and folded the beds back upon themselves, pushing them past the vertical until the Trenton and Nashville strata, northwest of and adjacent to the fault, dipped 70° to the southeast, and the older underlying beds became the uppermost.

The power that is equal to the thrust implied in such a fault and overthrow may readily be credited with the energy required and applied in the form of heat by older theories of metamorphism. But though the crystalline texture of the marble and dehydrated condition of the iron were thus accounted for, it would be difficult to explain why the metamorphic action was confined to the narrow limits within which these chemical changes occur, and why such action did not extend to the Maclurea limestone on the one hand, nor to the Nashville shales on the other.

The fact that crystallization of the limestone does not extend from the horizon of the widely distributed marble beds of East Tennessee into adjacent strata, points to the chemical attitude of the original deposit as the cause of their present condition, and it is not inconceivable that the marble was marble while still lying undisturbed in its bed of deposition.

It is to the accidents of tides and eddies of the Silurian ocean that the quality of this or that slab of marble is due; here ran a clear current, washing clean the white shells of brachiopods and the masses of coral growth; there, in stiller water, accumulated the ferruginous muddy sediment from the not far-distant shore or from the shoals of a shallowing sea. Here crystallization, aided perhaps by secondary arrangement of the lime, resulted in calcite; there a worthless shale is the product of compressed mud. Between these two extremes is the happy mean of composition of the first quality of marble, that is worth three dollars a cubic foot and is fit to adorn a lady's dressing table. Such marble resembles a

conglomerate, in which the pebbles are replaced by shells, and its quality is determined by its strength and by its color.

Strength is proportionate to the percentage of lime in the matrix of the rock, and depends also, upon the absence of cracks, and minute flaws. Color is due to the presence of iron and to its degree of oxidation.

The content of lime contributes to the strength of the rock, since it is the cementing substance, and the absence of ferruginous clay lends toughness in the proportion that a limestone is stronger than a shale; and minute flaws, so ruinous to the marble slab though scarcely visible in the block, are less likely to appear in the more calcareous stones, since they are often due to contraction of the original deposit in hardening, and this is less in the limestone than in the shale.

The term color, as applied to the Hawkins county marble, implies richness of tone and variety of mottling. The ground mass of the stone varies from pink to deep chocolate brown, with tints and spots of brighter red. The included shells and corals are usually pure white, with sometimes a creamy tint. The richer the hue of the ground mass, the more brilliant and varied its tones, the more pleasing the contrast produced by the spots and clouds of white, the finer the "color." Thus, "color" may deteriorate through lack of depth of tone, lack of variety, regularity of banding, or through the introduction of undesirable tints, as of a bluish green, which is not uncommonly seen in the inferior rock.

The combination of desirable effects is dependent chiefly on the amount and distribution of the ferruginous clay, and this is, to a certain extent, antagonistic to the conditions of strength; for depth of tone implies, usually, though not necessarily, a large proportion of iron with its associated clay, and this, as has been shown, tends to weakness and to flaws. Nor is this purely theoretical, as was proved by experience at certain quarries near Rogersville, now abandoned. Work was begun on a bed of good marble, which dipped about 50° from the horizontal; the quarrying was carried down vertically, and the color improved as the excavation passed into the underlying, though younger, shaly marbles; encouraged by the appearance of the blocks, many hundred feet were quarried before it was discovered that they fell to pieces under the saw.

This instance may also serve to illustrate the experimental nature of the development of these marble quarries. It is perhaps, not

too much to say, that since the first marble was quarried in 1838, up to the present time, all work in Hawkins county has been done by crude methods, with a view to immediate profit and in disregard of future economy. This arises from the fact that the proprietors and operators are farmers and townspeople of the immediate locality, possessed of small capital and little or no knowledge of mining operations. Work is often begun on the chance outcrop of "good color," and is then continued in whatever direction "color" leads. Such methods are to be regretted, because they injure the property thus developed by involving future operations in heavy expense, and they result in the production of much inferior marble, which affects the market unfavorably.

The opportunities for advantageous opening and extensive development vary very much throughout the range. At the extreme northeastern occurrence of the marble beds, they form, with the adjacent limestones, a broad hill, which has a steep slope of 80 to 100 feet to Caney creek. The pike road from Rogersville to Little War Gap rises on to this hill, and repeated folds of the strata, which here form a spoonlike basin, bring the marble to the surface at intervals for a distance of three-quarters of a mile along the road, beginning near the ford of Caney creek and extending north to six miles from Rogersville. At the last outcrop the strike of the rocks is at right angles to the pike and to Caney creek, which is close at hand. Here there are two openings on the same line of marble, leased by two different parties; Mr. Chestnut having a quarry immediately east and Messrs. Kyle and McDermott one west of the road on the slope to the creek. This division of interests is injurious to both parties, since each possesses what the other wants. Messrs. Kyle and McDermott have an excellent opportunity to choose their point of opening, to arrange their derricks for a minimum amount of hoisting, to provide good drainage for the quarry, and ample room for a dump below quarry level; but their stone is all near the surface and they have not a sufficient supply to justify large operations. Mr. Chestnut, on the other side of the road, controls the marble mass to which Kyle and McDermott should direct their operations, but his quarry is a square pit sunk vertically into the nearly flat surface of the hill; his dumping ground is limited and inconvenient, and he does a maximum amount of hoisting for a given output. It is a fortunate accident that subterranean channels drain the quarry and obviate the

otherwise necessary pumping. Were the interests of these two properties combined, the lay of the whole would afford an excellent opportunity for the extensive development which the character of the stone would justify. The belt of merchantable marble is probably not far from sixty feet wide, and much of the rock is of first class color; it dips 70° to the southeast and has walls of firm limestone. Adjacent to these quarries and extending as far as the ford of Caney creek are frequent outcrops of marble, and just at the bend of the marble belt is a large superficial area of good color, owned by Mr. J. N. Gouldy, but not yet prospected.

Following the horizon of the marble from this point southwest, there is an interval of five miles throughout which good stone is almost wholly wanting; over part of this distance the fault line probably cuts out the marble near the surface, and at other places the deposits were too muddy to crystallize into good stone. About midway of this generally barren outcrop is the small quarry known as Hayters. It has a good location on the point of a knoll, but produces only an inferior stone; the color is distributed in light and dark bands, too regular to be pleasing, and the darker layers are peppered with black spots. The stratification is particularly plain in this occurrence.

Beyond this unproductive belt, the marble comes in strongly for a distance of 4½ miles; its outcrop is along a steep slope parallel to Stock creek and fifty to seventy feet above it.

The conditions for open quarrying are most favorable, since the relation of the outcrop to the slope of the hill makes great economy of labor possible. The stone is of good quality, much of it having striking and attractive color, and its width varies from twenty to seventy feet, the lesser figure being unusual.

Test pits have been sunk at frequent intervals along this stretch and several quarries are now worked; Hounshall's near the northeast end; Saunders' and others near the middle, and Hasson's, toward the southwest. The last is one of the oldest quarries on the range and is the best developed. It contains marble of the best color and of sound character, and the bed of merchantable rock is seventy feet across. The other quarries are small openings, started after the haphazard fashion which is the rule. They produce stone of good quality, nevertheless, and turn out as much as Hasson's, as it is now worked by other parties. A mile southwest of Hasson's quarry, the ridge, which carries the marble in so

favorable a position for development, falls off suddenly to Cloud's creek and an area of lower rolling land intervenes along the strike. For perhaps three miles or more the outcrop of the marble is in the broad valley south of Short Mt., and it then rises on to the slopes of the river knobs, which lie between that valley and the narrow gorge which is now the channel of the Holston river. The topography here presents an interesting problem, inasmuch as the large stream would seem to belong to the broad valley. It is not impossible that the river has been transferred from its appropriate channel by process of retrogressive erosion, and the conditions required by such an hypothesis are found to exist in the occurence of hard and soft beds in the Cambrian; but sufficient study has not yet been given the question to remove it from the realm of theory.

The marble outcrop in the valley has received but little attention, but where it occurs on the slopes of the river knobs numerous openings are to be seen. At the point where the hills slope to an encroaching bend of the Holston is the old quarry, from which stone for the National Capitol at Washington was obtained. Other quarries in active operation, are opened at frequent intervals in the hills which extend toward Mooresburg; they are well advanced in their development, and if studied as a group would probably yield valuable information regarding the manner of occurrence of the marble. But the structure of the bed appears from casual examination to be complex, and I am unable to give the facts of thickness and position of the good rock.

Beyond these quarries the marble is cut out by the fault line, and Cambrian strata come in along the strike. Where the marble-bearing horizon appears again the rock is of a lighter color, the "strawberry" variety of Knox county.

The method of working is similar in all the quarries. The stone is loosened by hand drilling and wedging, very little powder being used, as the shock of a blast weakens the blocks. Advantage is taken of all joints and seams, and bosses that are free on all but one side are easily detached. Holes an inch in diameter are drilled a foot apart and a foot to eighteen inches deep on the one fast side, and iron wedges are driven into them between half-round irons; care being taken to drive the wedges evenly, large masses may be broken off without shock or strain.

When the marble lies solid in its bed a "channel drill" is

commonly used. This consists of an upright boiler with cylinder attached, carrying a clamp to hold a number of drills side by side and touching each other, and a slide on which they move up and down. The whole is mounted on wheels on a track. With each blow the drills cover a space an inch wide and six or eight inches long, and with each blow the machine moves slightly forward on its track. Thus a cut may be made of any desired length or depth, and a block may be freed on four sides.

Where a quarry is sunk below the surface all round, its floor may thus be "channelled" into squares of convenient size; a corner block is then loosened by a small blast and hoisted out, and access being gained to the under side of the whole mass, it is wedged up, stone after stone.

From the quarry bed the stone may be shipped directly to the mill to be sawn; or it may be dressed out square by hand and then shipped; or it may be sawn on the spot and the slabs be shipped. By the first process the quarryman saves labor, but he pays freight on much refuse rock and gets paid only for what the block saws out. By the second method the quarryman takes the expense of hand-dressing, but he gets paid for the cubic contents of his stone, and should not pay freight on more than he is paid for. If, however, the stone be not trimmed out perfectly square he will pay freight by its largest measurement and get paid by its least measurement, and hence if he dress at all let him dress well.

The third method saves labor and freight, but it is not always easy to establish a mill near the quarry, and the question of advantage can only be determined for each individual case. There is also a risk of breakage in shipping marble slabs, and there may be differences in freight rates, which cannot be foreseen.

Custom in the Rogersville district is in favor of shipment in the hand-dressed block.

The product of the quarries reaches the railroad at two points, Rogersville and Whitesburg. The latter is a station on the East Tenn., Va. and Geo. R.R., and receives all the output of the Mooresburg quarries by a haul of seven to eight miles and the fording of the Holston river at Cobb's ford. The quarries on the upper part of the belt from Chestnut's to Hasson's ship from Rogersville by hauling four to six miles. For this purpose a number of teams of eight to fourteen mules each are kept by a colored man, who also furnishes wagons and drivers, and trans-

ports the marble at so much per cubic foot, the rate varying from 18 to 22 cents according to the distance, the condition of the roads, and the size of the block. Blocks of all sizes, up to 120 cubic feet, are thus shipped, but economy and convenience tend to limit the size to 60 to 80 cubic feet; such stones are large enough for the ordinary uses of the marble slab, and weigh at the usual estimate of 180 pounds to the cubic foot from five to seven tons. Through the kindness of Mr. H. M. Aiken, the owner and president of the Tenn. and Ohio R.R. (as the Rogersville branch is now called), I am able to give the aggregate shipment of marble from Rogersville for the calendar year 1886 as 20,312 cubic feet, weighing 3,666,180 pounds, which paid freight on a haul of twelve miles to Rogersville Junction at five cents per 100 pounds, or altogether, $1833.39.

This total of 20,000 cubic feet may be taken as a basis for estimating the amount of money circulated by the Rogersville group of quarries. Statements of the cost of a cubic foot of marble delivered at the depot vary from fifty to sixty cents; but these are undoubtedly very much below the fact. It is possible that a stone may be taken from its bed and be dressed and hauled for sixty cents a cubic foot, but such an estimate fails to include the cost of clearing the ground, removing refuse and unsalable rock, purchasing steel and tools, and superintendence. In one instance, where two brothers worked with their men in the quarry, their product, sold at the depot for ninety cents a foot, just paid their expenses and left them nothing for their own labor. A careful estimate of the average cost, confirmed by a gentleman of long experience in the quarry, puts it at one dollar and a quarter per cubic foot, or double the expense stated by the operators. This discrepancy may be in part laid to the frailty of human nature, and in part to the fact that the quarrymen are really ignorant of the actual cost. They make a profit and are therewith content. It is certainly quite safe to say that the Rogersville quarries paid out in 1886 between twenty and twenty-five thousand dollars. Of this, perhaps four thousand was paid to the owner of the mule teams, and by him in turn paid to drivers at twelve to fifteen dollars, and to laborers at eight to ten dollars a month, and for feed, etc. The greater part of the sixteen or twenty thousand remaining was paid to quarrymen at $1.25, and to bosses at $1.50 or $2.00 per day. But a small part of this

money remains in first hands, however, for the laborers save but little; it passes through the hands of the saloon-keepers, who keep all they can get, and of store-keepers, who keep fifteen to twenty per cent. in store, to the farmers for produce or to manufacturers for goods.

There is reason for surprise in the expenditure of so large an amount of money through the quarries, as they are worked. As has already been said, they are operated without trained superintendence, without foresight, without knowledge of the methods of even such simple exploitation as the circumstances suggest; they are consequently worked wastefully, yet profitably.

The hand-dressed block of marble sells at from seventy-five cents to three dollars a cubic foot, according to color and soundness, the average price being probably about one dollar and seventy-five cents. It follows that there is a good margin, even for extravagant methods of work, and it seems certain that the investment of a larger capital under trained superintendence would be highly remunerative. Such investment should only be made, however, after a most thorough examination of the belt as it is now exposed, and in view of the absence of all known law in the occurrence of desirable stone it seems probable that exploration with the diamond drill might profitably precede actual quarrying. By means of the core brought up by such a drill the color would be determined in advance, the extent of the bed would be known and the existence of caves useful for drainage would be ascertained. The operations would be thus given a sound basis, and estimates of outlay and income would be something more than guesses.

Color in these marbles is like oil in an oil well. Said a bankrupt oil hunter to me once: "I calculated it all right; I put the profits at half and the expenses at double; but I forgot to calculate on dry holes."

A colorless quarry is as profitless as a dry oil well; but let him who would work Hawkins county marble be sure of his color and he may count on his profit.

THE EXTRACTION OF COPPER AT AGORDO.

BY T. EGLESTON, PH.D.

THE works of Agordo are situated in the province of Bellunese in the northwestern part of Lombardy. The ores which are treated there are very poor, containing only on an average 1.6 per cent. of copper. The works have been described several times,* but the process affords so many points of interest, parts of which might be applied in principle in this country, that, although such poor ores could not be treated in the United States, I have thought it worth while to write out for these works and for the treatment of copper at Mansfeld† the notes which I have for many years used in my metallurgical lectures, in hope that the information may prove useful to some of the graduates at the School of Mines and to others. The situation of the works with regard to labor is very favorable. So much of what is necessary to be done is of a character that does not require anything more than a readily acquired manual skill, that it can easily be done by children. The price of ordinary labor is low. Fuel is not abundant, but it is not dear, and that which is required for many of the operations can be had at a very low price. There is a market for the products and by-products of the works at rates which yield a small profit, and others still might be made if it was worth while to invest any more capital. The works are controlled by the Government, and the fact that the officials are waiting for promotion, and are pensioned when incapacitated for work either by old age or accident, undoubtedly has much to do with keeping down the cost of production. It is more than probable that but for this fact the works might not be able to run at such a low cost. For this reason but few economical details have been given in this paper, as it is unlikely that the cost of producing the copper at Agordo would be any reliable guide for the erection of works elsewhere, for which reason the reader is referred, for the commercial details, to the

* Traite de Metallurgie, Rivot, Paris, 1859, vol. i., p. 322: Annales des Mines, 5th Series, vol. viii., p. 407; 7th Series, vol. ix., p. 190; Church's Metallurgical Journey in Europe. N. Y. 1873. P. 1.

† The treatment at Mansfeld will be published in a subsequent number.

published records and such details as I have been able to collect for the use of the students of the School of Mines.*

The ore is found as a great mass of iron pyrites which has sometimes been as wide as 200 feet and which has been worked to a considerable depth. It does not appear to hold its width as it goes down. From 15,000 to 20,000 tons of these ores are mined annually. They are not always of constant composition or purity. They are compact iron pyrites, closely and very regularly associated with chalcopyrite. They are brass yellow and very fine grained, and, according to the analysis given below, very poor in copper. They have no gangue apparent to the eye, although the analysis shows it to be quartz.

	1†	2‡	3‡ Without gangue.
Copper,	1.6	1.6	1.866
Iron and zinc,	42	43.15	45.42
Sulphur,	50	50.25	52.714
Arsenic,	1.4		
Quartz,	5	5	
	100	100	100

The ore as it comes from the mine is sorted into four different categories. First, poor ore, which contains less than one and a half per cent. of copper; second, good ore, which contains from one and a half to three per cent.; third, rich ore, which contains from five to eight per cent. of copper; and fourth, ore containing lead. Of these, the poor is about 50 per cent., the good 47 per cent., and the rich 2 to 3 per cent. The mean yield of the ore is not more than 1.6 per cent. The minerals which it contains are chalcopyrite, very irregularly disseminated through it, some compound of antimony, and arseno-pyrite in small quantity, but sufficient at times to make the ores contain as high as 2.5 per cent. of arsenic, and antimony. Though the amount of impurity is small, it is generally in very large proportion in comparison to the copper present, so that it causes a great deal of difficulty in the process. The ore

* Tables to illustrate the metallurgical lectures at the School of Mines. N. Y. 1871.

† Rivot 2d., vol. i., p. 298.

‡ Annales des Mines, 5th Series, vol. viii., p. 414.

has also associated with it not more than 3 per cent. of zinc in the condition of blende, and galena, which contains a small quantity of silver, irregularly scattered through the mass, and also a small quantity of tin and a trace of cobalt. The gangue is principally quartz. The mines have been worked since the commencement of the 16th century. They were, however, then mined in large chambers, and were at one time entirely closed for several years on account of very extensive caving. They have only been properly worked since the commencement of this century. They are now treating about 20,000 tons a year.

Although the treatment of this ore is very difficult, it is very interesting. Some ores of this description are frequently found, although to be worked they generally require to be much richer than they are at Agordo. The treatment used there is, in many cases, applicable elsewhere to such ores when they cannot be enriched by mechanical preparation. At Agordo about one-third of what the mines produce is of no value, as it does not admit of dressing; the ores treated are simply hand-picked and classified as fine, poor, medium and rich ores. The rich ores are always found in very small quantities. They amount generally to not more than two and a half per cent. of those treated, and rarely ever yield over 6 per cent. of copper. They do not always yield as much as this, and are sometimes as low as 4 per cent. They are sent at once to the treatment in the dry way. The mean ore averages from 2 to 4 per cent.; the poor from one-half to 2 per cent. The smalls vary from 1 to 2 per cent. They are the debris of all the others, and a result of decomposing pyrites. They form about 15 per cent of all the ores. All of these last ores are roasted for lixiviation. The mean of all the ores is not over 1.6 per cent. The works are situated on a stream which is not navigable, and are only a short distance from the mine.

The object of the process is to drive off a certain portion of the sulphur, which is lost as a gas; to collect a certain other portion, which is afterwards refined; to concentrate the copper in such a condition that part of it can be leached and part of it made rich enough to be treated in the dry way.

The treatment consists of two parts, that in the wet and that in the dry way, certain parts of which are common to both. As a whole it consists of nine operations.

WET WAY.

1. Roasting the ore.
    a. Roasting in piles.
    b. Roasting in kilns.
2. Treatment of the sulphur.
3. Lixiviation of the crusts of the roasted ores.
4. Precipitation of the copper.
5. Crystallization of the iron sulphate.

DRY WAY.

6. Fusion of the rich ore kernels and cement copper in a shaft furnace for mattes.
7. Roasting the matte produced.
8. Fusion for black copper.
9. Fining and refining the rosette copper.

WET WAY.

The ores are roasted in piles or stalls in which a part of the sulphur is collected, and give as product: first, roasted ores containing sulphates; second, a certain quantity of enriched ores resulting from the concentration of the copper in the centre of the pieces where the air could not reach. These concentrated ores are called kernels. These are broken out by hand and treated with the rich ores. The crusts containing the sulphates are by far the larger proportion. These are lixiviated and give as the result a mixture of copper and iron sulphate. The part which is not dissolved still contains some copper as oxide. These are dried and again roasted, being used to make the cover of the roasting heaps, and are again lixiviated. If there are any large pieces in the residue remaining after this second lixiviation they are sieved out and again roasted and washed a third time. After this third washing the mud does not contain sufficient copper to make it worth while to treat it and it is thrown away. The wash waters resulting are heated to 50° or 60° B. and are then treated by iron. , This process is known as cementation. The result is copper mixed with the subsulphate of iron and some compounds of iron and arsenic. The material so formed is added to the rich and concentrated ores and treated in

the furnace. The sulphur collected on the roasting heaps is refined and sold. The waters containing the iron sulphate are concentrated and crystallized and the iron sulphate is sold.

1. Roasting the Ore.

a. Roasting in Piles.

The roasting is conducted in the open air in pyramidal piles, which are placed under sheds, so that the sides may, if necessary, be closed with planks for protection against the wind. These piles are made on a slightly inclined area and are built up in such a way as to collect the sulphur. In order to prevent the decomposition of the copper sulphate when it is formed on the outside of each piece of ore, the temperature must not be high. To form the pile, an excavation is made to the depth of 1.30 m., which is filled up with fine ore which has been previously completely lixiviated. In this filling of spent ore a number of upright posts of wood are placed whose tops come to the level of the ground. These burn out when the pile is lighted and serve subsequently as air channels.

The capacity of the pile is 200 to 300 tons.

Quantity of wood used for the 200 tons,	5.2 to 6 cubic meters.
Width of the pile at the base,	6 meters.
Width of the upper part,	4 meters.
Height of the pile,	2 meters.
Length of the pile, very variable, generally about,	7 meters.
Number of piles,	60 to 65.

Wood of inferior quality is placed on the ground leaving spaces between each piece to make the air-channels and form the first layer. Large ore is then placed on it, then small ore and so on. When the ore so piled has reached the height of 0.65 m., five or six spaces are left parallel to the short sides of the pile and at equal distances from them and reaching across the whole pile. These are filled with fine ore, the object being to prevent too easy an access of air across the pile. If this was not done there would be danger of fusion of the large pieces and of the transformation of the copper sulphate already formed in the crusts into copper oxide, which is insoluble in water. These walls of fine ore are continued to the top of the pile. When the pile is finished, large stones are

placed around it at the bottom, upon which the cover rests, the spaces between serving as openings to the air-spaces in the lower part of the pile. The cover is made of two layers. First about 0.30 m. of fine ore is laid up regularly on the sides and patted down with a shovel. Over this about the same amount of fines, which have been leached out, are placed, the sides are made complete before the pile is lighted, but the top is not completed until afterwards, so that the whole cover will be from 0.50 to 0.60 m. deep. It is thus partly put in place while the pile is being made and partly after it is lit. The pile is lit either at the four corners or upon all sides at the same time by introducing shavings left in the channels for this purpose. This is quite easy, as the large pieces of ore serve as chimneys to draw the air. When the pile is entirely lit, which will be in the course of 5 to 6 days, the flames come out of the chimneys; the cover is then completed and repaired wherever it is broken in. The space around the cover at the bottom is closed. The wood burns out in from 24 to 36 hours. During this time, and in fact until the pile is wholly lit, it must be carefully watched to make good any cracks to prevent any excess of temperature in any part of the pile. After it is well lit and the cover made good, it needs no watching until the sulphur begins to collect. After the wood is burned the combustion takes place by virtue of the sulphur, the temperature being kept as low as possible so as not to fuse the ore.

The process of roasting is conducted in such a way that there is not enough air going through the piles to transform the whole of the sulphur into sulphurous acid. Part of it is volatilized as such and collected, and part of it is concentrated in the interior of the ore. The copper sulphide, in the exterior of the pieces of ore, is changed into sulphate. As there is a large portion of iron sulphide, it must not all be transformed into sulphate, for the amount of iron required for the precipitation of the copper would then be too great. To effect complete separation of the copper, the property which sulphide of copper has of becoming concentrated in the centre of the pieces during the roasting is made use of. This method is called kernel roasting. The concentration is always more complete in the large than in the small pieces of ore. In the fines it does not take place at all unless they have been compressed. It is always most effective in the part of the ore containing an excess of pyrites and free from quartz. The sulphur is thus made to enter

into four different forms: sulphurous acid, which is lost; sulphur, which is collected and refined; sulphur, which concentrates in the interior of the kernels of each piece of the roasted ore; and sulphuric acid which forms copper sulphate in the crust. During the whole time of roasting, a considerable part of the arsenic is carried off as sulphide of arsenic and arsenious acid, which escapes in such quantity as to render the ore considerably purer than it was. The sulphur does not commence to collect in the upper part of the pile until the end of about 6 weeks. Little basins, 0.25 m. in diameter, are then made in the cover, and as it is very thick the sulphur condenses in them. Twice a day the sulphur is removed with spoons. These basins become rapidly heated, and as soon as they have become too hot to contain the sulphur in the liquid state, they are filled up and others are made in different positions. When the combustion approaches the top, or 5 to 6 weeks before the pile is burned out, the cover is so hot that the basins are no longer of any use and they are filled up. The roasting lasts about 9 months, and when it is finished the pile is left to cool for about 4 weeks. The reactions which take place on the fine ore are different from those which take place on the large pieces. The schlicks in the separating walls are quite close together, so that the air does not circulate freely through them. The roasting is done very slowly, and, as sufficient air for oxidation does not enter, a part of the sulphur is sublimed and with it a certain portion of the arsenic and antimony. Among the large pieces the air can circulate readily and the combustion of the sulphur can take place, but only on the surface of the pieces. The combustion will for a certain time be confined to the parts of the pile towards the outside. By the time that it has penetrated to the interior of the pile, the heat will be high enough to make the interior of the pieces of ore enter into a state of pasty fusion. In this condition, any oxide of copper that may have been formed on the outside of a piece of ore from decomposition of the sulphate, meeting with an iron sulphide is transformed at once into copper sulphide. The copper sulphates and oxides formed by the oxidation of the copper pyrites also act on each other and copper is precipitated. The sulphur sublimed from the interior acts upon this, and the result is, copper sulphide is formed and sulphurous acid given off. The copper sulphide is fusible. It enters into a state of pasty fusion and flows towards the centre of each piece of ore, and the sulphur of the out-

side is thus absorbed into the interior. The roasting then becomes very difficult, because the air cannot penetrate the pasty mass. These reactions continue until there is little or no copper on the outside of the pieces of ore, except such as has been converted into oxide, at a time when there was not sufficient sulphur present to produce the concentration. This copper is, for the most part, saved in the subsequent treatment of the fines of the crusts. When any silver is present in the ore, it concentrates on the outside of each piece, being frequently found as very fine silver spangles, as if the ore had undergone some galvanic action.

The kernels from poor ore contain from 3 to 6 per cent. of copper according to their size. From mean ore they contain 6 per cent., and from rich ore from 9 to 10 per cent. or even as high as 15. The fine ore contains but very little sulphide. Most of the copper is either sulphate or oxide. When the roasting at the end of 6 to 9 months is finished, the pile is taken to pieces. The cover, kept separate from the fines used in the base of the pile, is made to pass to its third lixiviation. From the interior the fine ore furnishes the material for the first lixiviation. The large pieces are broken by children, who do it with a great deal of skill and precision, and the interior or "kernel" is separated to be sent to the ore furnace. The outside is sent to the first lixiviation. In the solution there will be iron sulphate and subsulphate, copper sulphate and some portion of zinc sulphate. The kernels contain from 20 to 50 per cent. of copper when they are perfectly separated from the poor exterior, but, in order to be certain not to lose copper, much of the outside is frequently left around them, so that they do not contain on an average more than 6 to 8 per cent. The outside crusts frequently contain as low as .1 to .4 per cent.

There is found at Agordo a bed of white iron pyrites, containing a very small quantity of copper, which decomposes rapidly when exposed to the air. It is only worked in the summer time. This ore is crushed, and it and some of the fines from the lixiviation which still contain sufficient copper are moulded into bricks, which are conical in shape, 0.10 m. high by 0.15 m. in diameter. They were formerly made hemispherical on account of the ease with which they could be tipped from the moulds, but this form was abandoned. Larger bricks might be easily made, but this size has been found by experiment to be best, for the reason that the larger ones are more difficult to handle and break more easily, and are

not always even roasted, in the interior. The size of a grain of ore must be small for the most effective results. The fine ores are mixed with the green vitriol mother liquid, which is from 25° to 30° B., until they are of the consistency of pulp. The mixture is then stamped into brass moulds, of which there are three in a single casting. They absorb about 10 per cent. of their weight of the mother liquid, and, in order that the amount should be as much as possible, the fine ore must be quite dry before it is treated. When stamped the bricks are turned out of the moulds, placed on boards, and carried to the drying ground to be dried, which takes about three weeks of exposure to the air and sun. The drying must not be hurried, or they would be liable to crack and fall to pieces in handling. When quite dry they weigh about 2 kilograms each. They must be dry before they are treated. To effect it they are piled up on the outside and top of the roasting heaps, where the drying is finished. They should be quite hard in order to allow handling. They become hard in from three to four weeks. This is produced by the oxidation of the particles affected by the mother liquors. A single man in nine hours can wet up, make and carry to the drying ground 600 of these bricks. They should not be too large, on account of the difficulty of handling them and also of roasting them completely. It is necessary to keep the grains which are used of a limited size also, as much space between them prevents the formation of the kernels. When they are quite dry they are made up into heaps containing from 70,000 to 80,000 bricks. The pile is made with or without a cover. When there is a cover it is made of two parts. Fine unroasted ore is put directly over the bricks, and this is covered with the fines which have been leached out. The fine ore must be perfectly dry, for the bricks are quite hygroscopic, and quickly absorb all the moisture it contains. When the fines are damp, or it is not convenient to dry them, they are not used in the cover. These bricks are then roasted in much smaller heaps than when they are covered. The time of roasting the heaps varies according to the size of the pile. Small ones take from four to five months; large ones from ten to twelve. When the pile is burned out, each brick is broken to ascertain if it is fully roasted, and those which are not, are put into the next pile. The amount of labor per ton of ore required to make these bricks is seven-tenths of a day, and for roasting them three-tenths of a day. The ore in them is never over-

roasted. A much larger amount of copper is extracted in this way than was possible when all the fines were roasted in heaps with the large ore, the gain being nearly 75 per cent. Well roasted bricks have a reddish color. They are very hygroscopic, and if they are left exposed to the air they increase in weight after a time as much as 8 to 9 per cent., and fall to pieces, and become covered on the outside with soluble salts of iron and copper. When they are taken from the pile they readily absorb water, and when placed in it hiss and give out a considerable quantity of heat. This brick-making has very much increased the amount of material which is dissolved in the water, but the whole of it is not copper; it is mostly iron sulphate. The exact amount of the increase in copper sulphate is not known, but it must be quite large, as the iron sulphate is much more easily decomposed by heat than the copper sulphate, and it is, therefore, probable that but little, if any, of the copper sulphate formed has been decomposed.

The concentration of the copper in the centre of the large pieces of ore has been known and studied for many years. Formerly it was not possible to obtain kernels in the fines, but since the introduction of brickmaking with the fines, kernels have been obtained in them also. Formerly, as the fines were placed in the pile, each particular piece of fine ore acted and was acted on for itself alone, and as it was surrounded on all sides by air it became almost wholly converted into sulphate. In any case its size was too small to show the concentration even if it took place. If the temperature was raised too high the concentrate was decomposed into oxide. In the large pieces the reactions do not take place in the same way. The air can only convert into sulphate that part of the ore which is on the outside, and part of this is transformed by the heat into sulphide, when it melts and runs into the interior of the mass towards the centre. To effect this reaction absolute molecular contact is required. It may even happen, when the heat is sufficiently high to melt the ore of a piece, that the melted material flows down on to a piece below it, and may even cause the transfer of the copper from one piece to another, because absolute contact is produced by the melting of the ore.

The composition of the kernels is :*

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* Annales des Mines, 5th Series, vol. viii., p. 429.

Copper,	41.64
Iron,	28.76
Sulphur,	29.38
Total,	99.78

The composition of the crust is:

Copper sulphide,	4.23
Copper sulphate,	3
Iron sulphate,	0.18
Protoxide of iron,	85.7
Quartz,	2.85
Water,	3.04
	99.00

It might be an improvement to have the large pieces broken between rolls placed not very close together. When the operation has been properly conducted, the interior of the kernels will be of a purple to a violet color. The separation between them and the outside crust will be very distinct.

Only a very small quantity of the sulphur is collected in either the pile or stalls, not over 4 per cent. of the sulphur contained in the ore. This quantity is so very small that the method was modified by roasting in stalls, so as to give more sulphates, in order to concentrate the copper in the interior of the ore and give a larger proportion of sulphur.

b. Roasting in Stalls.

The stall known as the Styrian stall was invented at Mühlbach, in the expectation that its use would cause the saving of a much larger amount of sulphur, and also increase the yield. It is really only a pile with four walls, one of which must be taken down for charging and discharging it. It was at first built entirely rectangular, Figs. 1 and 2, but it is now often made round at the ends. Its length is 15 to 20 m., the width 5 to 7 m., and from 2 to 3 m. high. The thickness of the walls is 1.75 m. The foundation is made by excavating, as in the pile, and filling it in exactly in the same way. On top of this, in charging the kiln, a central canal, running the whole length of it, is made, which communicates with a series of chimneys made through the ore. The hearth or bottom is made of clay, and is flat, or nearly so. It is composed of a series of very low inclined planes. The bottom of each of

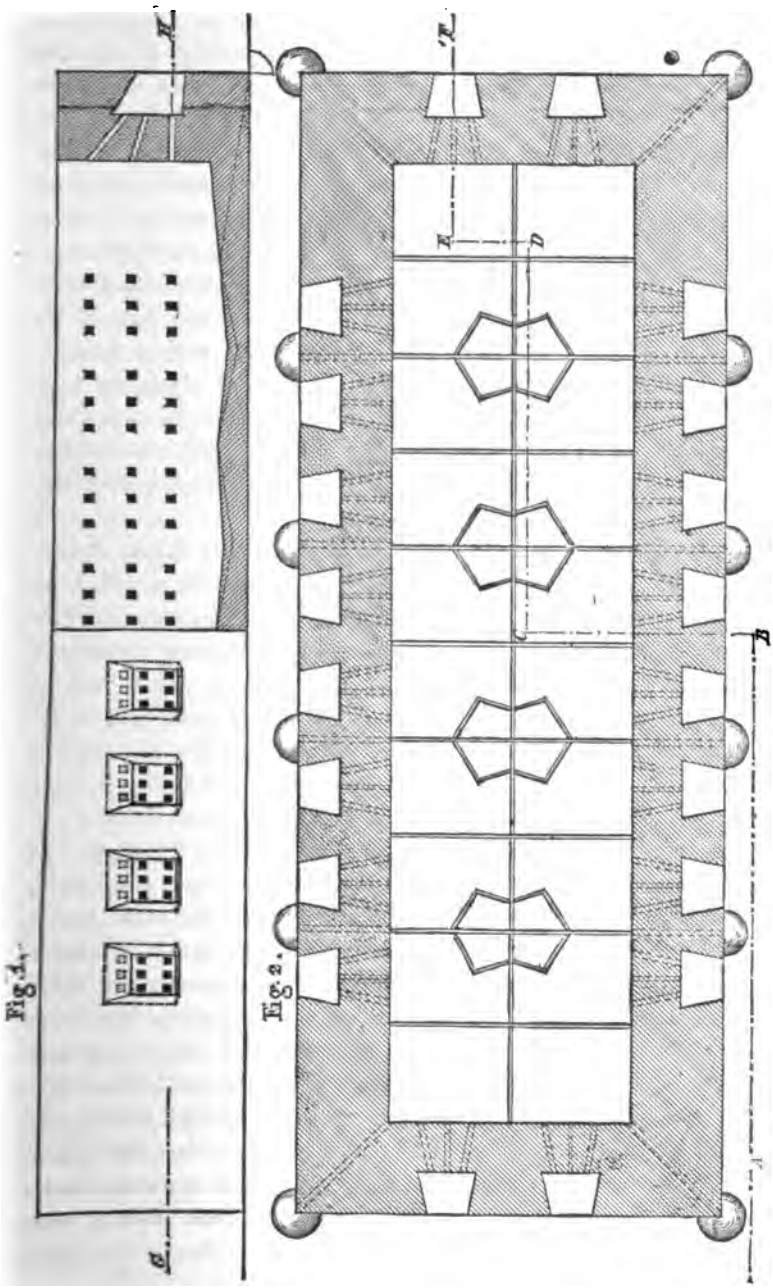


FIG. 1.—Elevation and vertical section on the lines A, B, C, D, E, F.
FIG. 2.—Section and projection on the line G, H, Fig. 1.

these inclines communicates with the exterior by channels, which run into little hemispherical basins on the outside, Fig. 2. In the early construction a very large number of these inclines, with corresponding basins on the outside, were made, but it was found that the maximum of sulphur was collected with eight basins on the sides as well as with more, so that the practice was finally adopted of using four on each side, with one at each corner, or twelve in all. At about half the height of the kiln, Fig. 1, eight embrasures, on each side and two at the ends, directly above the basins on the lower level, are made in the masonry at about half of its depth. These are closed with a sheet-iron cover with a handle. They communicate with the interior by sets of three or four openings, which are evenly distributed from the bottom to the top for the purpose of collecting the sulphur. This would make either nine or twelve openings in all connecting these niches with the interior of the kiln.

In charging the kiln a part of the end wall is taken down, a bed of fuel is placed below, and above the ore is piled in horizontal layers of large and small pieces alternately. In the centre of the stall, at the highest point of the inclines, chimneys are constructed, built of bricks made of fine ore, either mixed with a little clay or the iron sulphate mother liquors, and compressed like ordinary bricks. When the kiln is full the end wall is built up. It holds usually about 300 tons of ore. The ore is then covered over with fine ore and the spent material from the lixiviation vats, which is stamped down to make a cover. Through the chimneys lighted wood and charcoal are thrown, and the ore is lighted through the canal in the bottom of the kiln. The cover on the top, when the pile is lighted, is completed, and the chimneys are filled with bricks and ore, so that the kiln after it is once lit is worked as if there were no chimneys; as far as possible the continuity of the horizontal beds of large and small pieces is established through the chimneys. On starting a new stall when it is cold, there is such a great thickness of stone through which the vapors of sulphur have to pass, that they are much more thoroughly condensed than in the pile, but the mass of stone becomes heated towards the last and retains the heat, so that after a time but little sulphur is collected. The roasting gives rise to the same series of reactions which takes place in the pile, the concentration taking place just the same as there, in the centre. In the fine ore

the roasting is much more complete and better done, as the temperature is higher, and, as the fines are compressed, the contact, made either by the sulphur in fusion or by the compression, causes much finer and richer kernels to be formed than in the pile. In the piles, where bricks are not made, the fines make no kernels, but in the stalls they do. This production of kernels without much sulphates was the difficulty in the use of the kilns. The production of the most kernels requires a high heat gradually raised, and a long time, with little or no access of air. The high heat that produces the kernels, however, destroys the sulphates, producing oxides in their place, which are not soluble, so that what was gain on one side became a loss on the other, and the kilns were finally abandoned on this account. On the outside sulphates and oxides are principally formed, but there is a small amount of sulphides still remaining there. The sulphur is distilled, melts, and runs first into the basins, which are on the level of the ground. Only a small quantity is collected here because the ore becomes rapidly heated, and the sulphur is volatilized and condenses higher up. It soon commences to collect in the upper openings, coming from the lower part of them first, and the upper towards the last.

The roasting in these stalls lasts from five to six months, and 288 tons are treated at a time. A much larger quantity of sulphur is gained than with the other method, but only about 1½ per cent. is collected. The sulphur is always impure, because in getting it out some of the clay is always taken out with it. It must be refined before it can be sold. It is of no great value as it contains arsenic. This stall is not considered as very successful, for though double the quantity of sulphur is collected, the ores were over-roasted, some of the copper sulphate being decomposed, and, though most of it is subsequently regained, there is a loss of fuel, as an extra quantity of ore must be treated in the second and third operations. The cost of roasting is also somewhat higher, as one end of the kiln has to be taken down to discharge it, and has again to be rebuilt when it is filled. It has also another disadvantage, which consists in the fact that it is not possible to treat the whole of the residues from the lixiviations, as the cover and internal partitions do not give the surface to utilize it, so that on the whole pile roasting with the fines made into bricks has been found most advantageous.

In taking out the charge it is found that the ores, with 2 per cent. of copper, give from 12 to 14 per cent. of kernels, which

contain 4½ per cent. of copper, 76 per cent. of shells or crusts, with 1$\frac{3}{10}$ per cent. of copper sulphate, which are leached, and 10 to 12 per cent. of crusts, which are too poor to treat, and are thrown away. The amount of sulphur collected is not more than from 1½ to 4 per cent.

When the piles are taken down or the kiln is discharged, the large and the fines are carefully separated. The large pieces are broken by children, more than 100 of whom are employed, who work in the open air near the kilns and piles. They are paid by the day, on condition of separating 54 kilos of kernels each day. They acquire great skill in doing it, and easily separate the kernel from the outer crust, without breaking it, with very light blows of a hammer. They also pick out the ore which has not been sufficiently roasted, which is sent back to the next roasting. The outside crusts are separated into two portions, in one of which, which is on the extreme outside, there is so little copper that it is thrown away, and the middle part is sent to lixiviation. The proportions of the different products are :*

			Percentage of copper extracted.
Earth, ...	—	86.74	.0704
Rich kernels, ...	89	11.78	5 02
Poor kernels, ...	11	1.48	3 45
	100	100.00	8.5404

2. Treatment of the Sulphur.

The ores contain on the average 50 per cent. of sulphur. Every effort is made to collect as much of this as possible. When the temperature rises sufficiently high in those parts of the pile or kiln where there is but little air, the sulphur volatilized in the cooler parts of them is condensed in a liquid state. To collect it, a workman walks over the top of the piles and kilns, and where he sees the most sulphur collecting, he makes with a stamper little basins 0.25 m. diameter. These basins become hot after a time and no longer collect the sulphur, when they are filled up and others made so long as any sulphur condenses. Every day the man in charge walks over the pile and takes up the sulphur, which is condensed, with an iron spoon. It is removed from the embrasures or the top of the kiln in the same way. The quantity collected in the

* Annales des Mines, 5th Series, vol. viii., p. 434.

pile is only .2 to .4 of 1 per cent. of that contained in the ore, and is entirely taken from the top. In the stall the sulphur collects first on the bottom, then in the embrasures, and then on the top, where the basins are made like those in the piles. The quantity collected on top is very small, as by the time the sulphur reaches there, both the ore and the masonry are hot. The total quantity is much larger than in the pile and is 2.2 per cent.

The sulphur obtained in both pile and kiln is very impure and must be refined. It is heated and kept in fusion from 3 to 4 hours in cast-iron boilers with wooden covers. These are set in masonry with a fireplace below them. The boiler holds about 150 kilos of sulphur. Wood of inferior quality is used in the fire. After the sulphur is melted, the earthy matter is taken off as scums from the top, and the sulphur cast in moulds, into cannons. Two operations can be made in a day. The scums or crasses always contain some sulphur, and as they are thrown away this is lost. When the liquid part has been removed from the pot, a new charge is made, and so on until the number of operations are completed. An iron rod is then placed in the midst of the heated mass and is allowed to cool there. The whole mass is then gently heated to enable it to be raised from the pot. At the close of an operation these cakes are treated, and what sulphur can be easily extracted is saved, and the rest is thrown away. The work on 150 kilos of sulphur lasts from 4 to 5 hours. The workmen are engaged working the sulphur for three shifts, and they use .718 cubic metre of wood per ton of sulphur. The loss in working the sulphur which is sublimed and condensed from the pile, is 2.5 per cent., while that from the stalls is 14 per cent., as there it is melted, and in running out carries fine stuff with it.

The sulphur, after purification, is cast into moulds of wood made in two parts, which are conical in shape. They are kept soaked in water to prevent the sulphur sticking to them. These parts are separated when the sticks are cooled and give rise to stick sulphur, known as "cannon" sulphur. The cast-iron boilers last so long and need so little repairs, that they do not cause any appreciable expense. This method of refining very easily separates any solid particles which are mechanically mixed with the sulphur, but does not separate any of the other impurities. The arsenic which it contains remains with it and makes the sulphur of inferior quality.

[To be continued.]

ON THE MOVEMENT OF SOLID BODIES IN WATER.

BY PROF. H. S. MUNROE.

RECENTLY the writer has been engaged in making some experiments with a view to determine the laws governing the movement of solid bodies in still and moving water, under the conditions found in ore-dressing practice. The investigation is still incomplete; nevertheless some results have been obtained which it is thought may be of interest to the readers of the QUARTERLY.

A body falling in still water moves at first with accelerated velocity, its weight acting as a constant force to increase its falling velocity. As the velocity increases the resistance offered by the water also increases. This resistance of course tends to counteract and lessen the effect of the accelerating force. This resistance increases with the square of the velocity, while the accelerating force, viz., the weight of the falling body, is constant. It is, therefore, evident that the accelerating force will be neutralized eventually, and that the falling body will then move with uniform velocity.

We may determine the laws governing the fall of regular spheres in still water as follows:

Let d = diameter of sphere in meters.
δ = specific gravity of sphere.
V = falling velocity of sphere in meters per second.
p = acceleration of sphere.
g = acceleration due to gravity = 9.81 meters per second.
γ = weight of one cubic meter of water.
π = 3.1416.

Then (Weisb., p. 596),

$$p = \frac{\text{motive force}}{\text{mass}}$$

Or, in this case,

$$p = \frac{\text{weight} - \text{resistance}}{\text{mass}} \quad . \ . \ . \quad 1.$$

As the sphere is submerged in water its

$$\text{weight} = \frac{1}{6}\pi d^3(\delta - 1)\gamma \quad . \ . \ . \quad 2.$$

From Rankine's Applied Mechanics, p. 598:

$$\text{resistance} = \frac{1}{2}\ \frac{\pi d^2}{4}\ \frac{V^2}{2g}\gamma \ . \ . \ . \quad 3.$$

Or finally:

$$\text{mass} = \frac{1}{6}\,\frac{\pi d^3 \delta\gamma}{g} \quad . \quad . \quad . \quad . \quad 4.$$

From 1, 2, 3, and 4, cancelling and reducing,

$$p = \frac{\delta - 1}{\delta}\,g - \frac{3}{8}\,\frac{V^2}{d\delta} \quad . \quad . \quad . \quad . \quad 5.$$

Let $P = o$, and substituting for g its value, 9.81 meters,

$$V = 5.11\,\sqrt{d\,(\delta - 1)} \quad . \quad . \quad 6,$$

which is the equation for the velocity of a sphere falling in still water after it has reached the period of uniform motion, as given by Rittinger and others.

In practice we have irregular ore grains to deal with, instead of perfect spheres. For such grains Rittinger found by experiment, for rounded ore grains,

$$V = 2.73\,\sqrt{d\,(\delta - 1)}$$

For flat grains,

$$V = 1.92\,\sqrt{d\,(\delta - 1)}$$

For oblong grains,

$$V = 2.37\,\sqrt{d\,(\delta - 1)}$$

For average grains,

$$V = 2.44\,\sqrt{d\,(\delta - 1)}$$

In the above, d equals the diameter of the sieve opening through which the grains will pass.

In most forms of ore-dressing apparatus, in jigs for example, we have to deal, not with single isolated grains, but with numbers of these grains moving together. The smaller grains move in the interspaces between the large grains, and consequently in constricted channels. The large grains also, so far as their movements are independent of the surrounding grains, as in the separation of gangue from ore, and of one mineral from another, move in the interstitial channels between the other grains. That these channels must have great influence on the movement of the grains has long been recognized, and indeed was pointed out by Pernolet, one of the earliest investigators of the subject.

Nevertheless Pernolet and those who have followed him, Von Sparre, Rittinger, and others, have been content to assume the formulæ for free falling grains as universally applicable, and have

drawn therefrom the arguments and data for the close and accurate sizing characterizing the Continental system of ore dressing.

It is, however, possible to effect a very satisfactory separation on jigs, the material being sized between wide limits only, and in a very imperfect manner, as in the mills of the Lake Superior copper region, or even entirely without sizing, as at the St. Joe dressing works at Bonne Terre, Missouri.

It is evident, therefore, that we must revise somewhat our theories of dressing, and as a first step in that direction direct our efforts toward the determination of the laws that govern the movement of bodies in confined channels.

In formula 1

$$p = \frac{\text{weight—resistance}}{\text{mass}}$$

it is evident that the resistance only will be affected by the walls of the channel. To determine this resistance, lead shot of different diameters, 2 mm. to 16 mm., were suspended in a tube 20 mm. in diameter and subjected to the action of rising currents of different velocities. The buoyant effect in each case was measured by means of a sensitive spring balance, and the velocity of the water current determined by noting the number of seconds required to fill a vessel of known capacity.

It is evident that the result will be the same, whether the water or the shot be moved; the buoyant effect in the one case, or the resistance in the other, being a function of the velocity and of the relative size of the sphere and the tube.

From more than a hundred experiments made with this apparatus with spheres of different diameter, it appears that the buoyant effect or the resistance may be expressed very nearly by the following formula:

$$R = \frac{1}{2}\frac{\pi d^2}{4}\frac{V^2}{2g}\left(\frac{D^2}{D^2-d^2}\right)^2\left(1+\left(\frac{d}{D}\right)^{\frac{3}{2}}\right)\gamma \cdot \quad 7.$$

Or, more approximately, by the empirical formula:

$$R = \frac{1}{2}, \frac{\pi d^2}{4}, \frac{V^2}{2g}, \left(\frac{1}{1-\left(\frac{d}{D}\right)^{\frac{3}{2}}}\right)^2 \gamma \cdot \cdot \cdot \cdot \cdot \quad 8.$$

R is the resistance and D is the diameter of the tube. Substituting this for Equation 3 and determining the value of V as before, we have

$$V = 5.11 \left(1 - \left(\frac{d}{D}\right)^{\frac{3}{2}}\right) \sqrt{d(\delta - 1)} \quad . \quad . \quad . \quad 9.$$

or for ratio $\frac{d}{D} = \frac{1}{10}$

$$V = 4.95 \sqrt{d(\delta - 1)}$$

for ratio $\frac{d}{D} = \frac{1}{4}$

$$V = 4.47 \sqrt{d(\delta - 1)}$$

for ratio $\frac{d}{D} = \frac{1}{2}$

$$V = 3.32 \sqrt{d(\delta - 1)}$$

and for ratio $\frac{d}{D} = \frac{9}{10}$

$$V = 0.76 \sqrt{d(\delta - 1)}$$

It will be seen that when the falling sphere is less than one-fourth the diameter of the tube its velocity is but little affected. On the other hand, as the sphere approximates the diameter of the tube, its falling velocity becomes very small as compared with that of a free falling body.

As it is the latter condition, rather than the former, that obtains in the movements of a mass of grains on a jig sieve, the importance of taking into consideration this retarding influence is at once evident.

Sphere of Maximum Velocity.

If in formula 9 we determine the maximum for V, we find that it corresponds to the value

$$\frac{d}{D} = 0.3968,$$

that is, the fastest moving sphere in a tube of given size will have a diameter about four-tenths that of the tube. Spheres of larger or smaller size will fall with less velocity.

Equal Falling Grains.

In order to effect a separation of two minerals of different specific gravity it is evident that the slowest grain of the heavy mineral must fall faster than the quickest grain of the light mineral. If we take, for example, a series of tubes of 1 mm. diameter, representing the interstitial channels in a bed of galena on a jig sieve, the quickest grain of quartz would have a diameter of 0.4

mm. From equation 9 we find that a grain of galena having the same velocity in a 1 mm. tube has a diameter of about 0.015 mm. All grains of galena of larger diameter* than this will fall faster than the quickest grain of quartz, and will therefore resist the rising currents that will carry up the quartz grains. All grains of quartz larger or smaller than 0.4 mm. will have a less falling velocity than the maximum, and therefore can be separated completely from the galena grains.

We see, therefore, that *close sizing is quite unnecessary in jigging, provided that the work is so conducted as to give full effect to the separation in the interstitial channels.* Even in the case where no sizing is attempted, and slimes are treated with the jig sands, the loss will be confined to galena of such exceeding fineness that it is doubtful whether it could be saved by any method of treatment.

The principal objection, in practice, to this method of jigging is the imperfect concentration of the material passing through the jig bed. The "hutch work," as it is called, is much richer when the stuff is sized before jigging. This difficulty is overcome at Lake Superior and elsewhere by the retreatment of this hutch-work on finishing jigs. At Bonne Terre the hutchwork is classified in pointed boxes and the finest grades treated on side-bump tables.

The great advantage of this method of treatment is that the bulk of the tailings, both fine and coarse, is at once separated by the "roughing jigs," leaving but a small amount of rich stuff to be treated on the finishing jigs and tables, economizing machinery and handling. The method is especially well suited to the treatment of low-grade ores on a large scale. In fact it would not be possible to use the Continental system with profit at Lake Superior on account of the cost of screening, which would consume all of the profits now made at most of the mines.

In the foregoing discussion no account has been taken of the fact that the pulsating currents of a jig do not last long enough to result in uniform motion of the ascending grains. It can be demonstrated, however, that during the period of acceleration the advantage is with the small grain of the heavy mineral, and that

* It should be noted that the equation gives two values of d, viz., 0.015 and 0.915. Grains of galena .915 to 1.0 mm. would fall slower than the quickest quartz grain if they found their way into the interstitial channels. These large grains of galena, however, will not be lost, but will remain in the galena bed.

these short strokes further facilitate the separation of unsized material.

In conclusion, I must acknowledge valuable service rendered by my assistant, Mr. L. H. Rutherford, in these experiments and computations.

ON THE DRESSING OF NON-BESSEMER ORES.

BY G. W. MAYNARD AND W. B. KUNHARDT.

THE scarcity of Bessemer ore deposits in the Atlantic seaboard has led to continual large importations of foreign ore, and recently to heavy purchases of Lake Superior ore for eastern steel works. But the growing demand for Bessemer ore has also directed attention to raising the purity and richness of eastern ores to the Bessemer standard by dressing. Where shorter or cheaper haulage to centres of consumption compensates for such treatment, the dressed ore can compete with rich native or foreign ores to the extent to which fine material can in present practice be introduced into the blast-furnace burden.*

As the highest admissible phosphorus limit in pig-iron destined for the acid Bessemer process is, generally speaking, 0.10 per cent., the phosphorus in the ore must not exceed 0.001 per unit of metallic iron. Several large steel works keep to even lower limits.

* Mr. E. S. Moffat, General Manager of the Lackawanna Iron and Coal Company, states in a communication to the writers:

"For nearly three months we ran one of our Scranton furnaces on Chateaugay 'separated' ore [none of which is coarser than quarter-inch size] to the extent of 25 per cent. of the ore mixture in addition to the usual quantity of fines in the other ores. Subsequently we ran another furnace on 50 per cent. 'separated Chateaugay' for several weeks. In both cases this ore worked well and we had no trouble in using it. When working 25 per cent. of separated ore we had the furnace on four-fifths anthracite and one-fifth coke; when working 50 per cent. separated ore we used two-thirds anthracite and one-third coke. Chateaugay is the only separated ore we have used. I am not prepared to say how much dressed ore we could use with coke alone; I only know that we have worked 50 per cent. of dressed ore with one-third coke with good results, and are quite confident of being able to run continuously on that proportion."

Through Prof. William B. Potter, of Washington University, it is learned that the Bessemer furnaces of the South St. Louis Iron Company have at times run altogether on Iron Mountain dressed ore; some of this, however, is of coarse egg size, while the average might be called half-inch stuff. This practice was always satisfactory; the high blast pressure which was necessary promoted a large output.

Greater latitude is permitted in fixing the sulphur content, since much of the sulphur is removed by proper furnace management; 0.005 S per unit of iron in the ore is frequently allowed. A high percentage of iron and low silica are also important desiderata. In strict parlance a Bessemer ore is one which smelted alone, with reasonably pure flux, will make a uniform quality of Bessemer pig. *New Bed*, *Crown Point* and *Chateaugay* of Lake Champlain, and *Tilly Foster* of Putnam County, N. Y., have been the only large producers of such ore in the Atlantic seaboard. If we expand the definition so as to include the calcined Hudson River carbonate and the roasted sulphur and copper-bearing magnetite of Cornwall, Pa., both of which are largely used in admixture with other more strictly Bessemer ores, the list of undressed ores in the eastern territory of the United States which have contributed in any considerable quantity to the Bessemer industry is complete. Excepting this small number of active producers, to which might be added a few minor contributors and several well known, but hitherto scarcely developed, deposits of high-grade magnetite, none of the iron-ore bodies of the Atlantic States do in their crude condition satisfy Bessemer requirements. They are all either too lean or carry too much phosphorus—but not sufficient of the latter associated with a high percentage of iron, be it remarked, to yield any considerable output fit for basic Bessemer work. A wide and not unpromising field is therefore open for dressing enterprise.

The work that has been accomplished in this field is soon told. By means of simple sluice boxes, or washing trommels, sometimes supplemented by old-fashioned, slow-working jigs, the "washeries" which are dotted over many parts of New England and the eastern portion of the Middle States, separate gravel and ochreous clay from limonite. The work is often carried on by farmers in a small way, but the aggregate of ore so dressed is large. The washed product carries, however, with but very few exceptions, too much phosphorus—frequently in the form of intimately associated vivianite—to fit it for Bessemer furnaces, so that the treatment requires only the briefest notice here.

The magnetites which during many years supplied the active bloomary forges of northern New Jersey and the Champlain district were always dressed. The demand for blooms, however, is steadily declining, and the advent of the basic open-hearth is destined to

effect a still further and marked restriction in their use, so that capital refrains from investing in new mills to supersede the primitive plants which have so long been used for dressing the bloomary ore. The practice of forty years ago is that of to-day: the ore is partially calcined with wood in open heaps to make it friable; then it is stamped on a perforated cast-iron plate, and the fine broken stuff is sluiced, or jigged, without any attempt at previous sizing. This treatment enriches the ore from the 25 or 30 per cent. of iron it contains in its crude state to 65 per cent. of iron (= 90 per cent. magnetic oxide) in the concentrate—of course at the expense of no small loss of mineral in the tailings.

The first systematic concentration of iron-ore in this country, so far as the writers know, was undertaken about fifteen years ago at Iron Mountain, Mo. The process there, which was an outgrowth of the simple hand-jigging of surface fines, has since been developed to an excellent degree of efficiency by Prof. W. B. Potter, of Washington University. The Iron Mountain "surface-ore" consists of decomposed porphyry carrying liberated grains and pieces of specular hematite. This surface-ore and the mine dumps, which contain all the refuse derived from spalling and grading the underground, or "mine-ore," are hydraulicked *in situ* on a large scale to wash out a great amount of clay. The gravel and fines produced by this operation are still further cleansed in cone-washers. All material coarser than 1¼″ is then hand-picked to form a finished product, while the finer stuff goes through sizing trommels which classify into ⅛, ¼, ½, ¾, and 1-inch sizes for jigging. Bradford tray jigs are used on all sizes but the finest, for which the more expensive Hartz plunger jig is preferred. The proportions of iron and phosphorus in the dressing-ore fluctuate between wide limits; 300 tons of hydraulicked ore sometimes yield as high as 250 tons of concentrates, and, again, as low even as 50 tons. The separated ore runs about 65 per cent. in iron and most of it is low in phosphorus, so that the dressing operation yields a Bessemer product. The phosphorus occurring as apatite in the gangue is washed away except where the apatite crystals are firmly imbedded in specular mineral, as is the case in some of the "spalls," when an actual enrichment of phosphorus has been found in the concentrates. The tailings carry from 10 to 25 per cent. of iron, according to varying conditions. Much of this iron is finely disseminated through the porphyry, while some of it is, of course,

chemically combined with the gangue minerals; an average of 15 to 18 per cent. of uncombined Fe_2O_3 is, perhaps, as fair an average figure for the tailings as can be given. Three plants are now erected at different points of the iron property, with an aggregate 12-hour capacity of 600 to 900 tons (depending on the proportion of fines) of crude, hydraulicked ore. Each plant has two cone-washers with a corresponding set of screens, and for each screen there are two jigs. The cost of dressing, including hydraulicking (but without crushing, which is unnecessary), varies from 40 to 70 cents per ton of separated ore; the average is about 60 cents.

In 1882 a separator was erected at Crown Point, N. Y., for dressing the low-grade magnetite of the Crown Point Iron Co. The mill is referred to by Mr. A. W. Wendt, its designer, in an illustrated paper* describing a similar plant (now idle) at the Thael mine, Putnam Co., N. Y. The raw ore is crushed to $\frac{1}{8}''$ and sized for jigging, but it is remarkable that the sizing is confined to making only two classes of jigging ore—the coarser ranging from $\frac{1}{8}''$ to $\frac{1}{16}''$, and the finer from $\frac{1}{16}''$ down. Unless the ore possesses an open texture, so that very few "mixed grains" (part mineral and part gangue) are formed in crushing, such limited sizing must presumptively either restrict the capacity, or lower the efficiency, of the jigs. The average working is exhibited in the following figures:

Proportions.	Crude Ore.	Concentrates.	Tailings.
Percentage of iron	33–35	65.00	20
" " phosphorus	0.03	0.02	—

The annual output of the mill amounts to 5000 tons of separated product, each ton being obtained from 2.8–3.2 tons of crude ore.

Six years ago the Chateaugay Ore and Iron Company began erecting concentrating works at their mines at Lion Mountain, near Plattsburg, N. Y. Their latest plant, a large and well built mill, was put in operation in 1886. The lean dressing ore is a granitic rock carrying coarsely crystalline grains and aggregations of magnetite. Without any preparatory calcining it is broken down to one-fourth inch in Blake crushers and multiple-jaw fine crushers. The crushed ore, most of which is much finer than

* Transactions Am. Inst. of Mining Engineers, 1885, vol. xiii., p. 35.

quarter-inch, is concentrated on Conkling revolving tray jigs, without size classification of any kind. The results of the dressing are shown below: 3–3¼ tons of crude ore yield by concentration one ton of separated ore:

Proportions.	Crude Ore.	Concentrates.	Tailings.
Percentage of iron.....	35.0	65.5	18–22
" " phosphorus.....	0.025	0.015	0.033

At one time the concentrates were run up to 67 per cent. iron, but the higher market price then obtained did not compensate for the increased loss of iron in the tailings. At present 63 per cent. are guaranteed, and the product is kept slightly above that figure. The new mill has a 24-hour capacity of 600 tons of crude ore. It is furnished with three large Blake crushers, feeding into three others that are wider but more closely set; it has also the usual rejecting screens, and six multiple-jaw crushers each of which delivers to a Conkling revolving jig. The yearly output is upward of 50,000 tons of separated ore, much of which is shipped to Pennsylvania Bessemer furnaces.

At Negaunee, Mich., a large costly concentrating mill was built five years ago to work the jaspery hematite of the Jackson mine. The extreme toughness of the ore was the cause of ruinously rapid wear in the crushers and rolls;* besides this, the very intimate association of the mineral and gangue made any attempt at dressing the ore at best an extremely doubtful experiment. After a period of trials and failures the mill was closed, and it stands to-day a monument to the folly of embarking in a new enterprise of a technical character without submitting the vital question of feasibility to disinterested professional investigation.

This brief survey suffices to show that the field for ecomonic high-grade concentration of iron-ores has scarcely, as yet, been more than prospected. Only one company in the East—that of

* It may here be said that the use of the steam stamp for crushing certain classes of iron ore deserves consideration. The Ball stamp in its old form, and as improved by Mr. Leavitt, has hitherto been used exclusively on the tough native-copper ores of Lake Superior. Recent experiments with one battery in crushing the copper sulphuret ore of the Anaconda Mine, Montana, have proved so satisfactory that the erection of nine more batteries is contemplated.

Chateaugay—is regularly shipping "separated ore" to Bessemer furnaces in large quantity, but its signal success with a very lean ore is certain to stimulate the owners of other deposits, more especially as the field is broad enough to accommodate many workers without crowding.

Dressing Tests.

Dephosphorization is not the particular aim of the Chateaugay work, as the crude ore there runs well within the Bessemer limit for phosphorus. But the removal of this baneful ingredient will often be the point on which success hinges. When it occurs only in the gangue, and not too finely disseminated, its more or less complete elimination by dressing is a natural and almost foregone conclusion. Concentrating tests that have recently been made by the writers bear upon this subject and point to possible favorable effects obtained by calcining. An account of the work may therefore interest some readers.

The first ore to be tested was that of the Beach Glen mine of northern New Jersey. The ore is a hornblendic granite, heavily charged with coarse grains of magnetite. The mine was carefully sampled, and after some preliminary tests with a hand-jig, a 20-ton average lot of lean ore was shipped to Chateaugay, where through the courtesy of Mr. Williams, President, and Mr. Inman, General Manager, of the Chateaugay Ore and Iron Company, every facility was furnished for making a mill-run. The raw lump ore was passed through a rock-breaker into a Blake multiple-jaw crusher, set to a quarter-inch. As for special reasons close adherence to Chateaugay practice was desired, the ore was not sized further than to reject all pieces larger than quarter-inch. In this condition the crushed rock was fed continuously to a Conkling jig. The work, when once begun, was carried on without interruption until the conclusion of the test, which occupied four hours. Samples of the crude ore running into the jig, and of the concentrate running out of the ore chute, were taken every two minutes. The tailings were sampled in the same intervals at the point where they discharged from the jig and also 25 feet distant in the waste sluice. Each sample was put through a Lucop mill, crushing through an 80-mesh screen, after which it was quartered down for analysis with the following results:

TABLE I.

	Crude Ore.	Concentrate.	Tails at Jig.	Tails in Sluice
Iron, per cent.	41.75	65.50	24.92	21.68
Phosphorus, "	0.0643	0.0224	0.0799	0.0745
P in pig-iron, "	0.1534	0.0342	—	—

These figures show an increase of 56.8 per cent. in the proportion of iron in the concentrate over that in the crude ore, and a decrease of 65.6 per cent. in the phosphorus. By this dressing, therefore, a non-Bessemer ore was raised to the Bessemer standard. On the other hand the tailings run so high in iron that the yield, by weight, of the concentrate, as calculated from the above data, amounts only to 41.4 per cent. of the crude ore. In other terms, 2.4 tons of ore are required to produce one ton of concentrate. Even with this showing, at an estimated dressing cost of 25 cents per ton of crude ore, and allowing for the extra cost of mining 2.4 tons of rock to obtain only one ton of product, there are many localities where such ore can be worked to fair profit. With improved methods, particularly with systematic sizing, by which fine and coarse material are separated for jigging, better results will accrue. Moreover, the coarse-grained texture of many magnetic ores allows of their thorough disintegration without crushing down to quarter-inch, so that a portion, at least, of the dressed product will generally be of fairly coarse size.

The dressing of an Adirondack magnetite, exhibiting much finer mineralization than the New Jersey ore, presented an attractive, and, as it proved, an instructive problem.

The rock is an intimate mixture of magnetite, hornblende, quartz, mica, apatite, and garnet; by simple macroscopic examination it appears to be a hornblendic gneiss carrying a large proportion of magnetite. The intimate mixture of mineral and gangue pointed to fine crushing for disintegrating the ore, but as blast-furnace practice limits the fineness of the product, a condition was thereby imposed at the outset on any dressing operations. In making the tests about to be described, it has been assumed that ore sizes as fine as 16- to 35-mesh could be marketed if mixed in small proportions with coarser material, but that all mineral reduced to particles finer than a 35-mesh size must be regarded as loss.

As only 1900 pounds of ore were available for experiment, the work was necessarily done on a small scale. The investigation began with a series of crushing and sizing tests, the purpose of which was (1), to classify the ore for subsequent jigging; (2), to ascertain the proportion of waste fines thereby produced; (3), to determine how this waste could be minimized; (4), to find, in connection with jig-tests, how coarse a grade of ore could be successfully concentrated.

TABLE II.

RAW ORE. Over-2-mesh stuff after passing through Dodge breaker.	Pounds of Ore Crushed.	Size of Products in Meshes per Inch. Weights in per cent.										Total Products in per cent.
		Over 2	2-4	4-6	6-8	8-10	10-12	12-16	16-20	20-35	Thro' 35	
a. Thro' Rolls at 11/16"	274	75.1	13.7	1.5	1.3	1.8		2.0		1.6	2.9	99.9
b. " " 8/16"	206	48.5	32.5	7.8	1.9	2.2		2.4		1.9	2.9	100.1
c. " " 5/16"	100	20.0	45.2	15.5	4.2	4.0		4.3		3.2	5.0	100.9
d. " " 3/16"	268	—	5.6	45.4	13.2	12.5		9.3		5.8	6.6	98.5
e. " " 1/16"	137	—	1.0	15.5	27.2	27.0		16.4		4.0	7.3	98.4
f. " " 1/24"	24	—	—	4.2	6.3	25.0		33.3		15.6	16.7	101.1
	338	—	—	0.3	25.5	17.0	9.8	5.6	15.2	11.0	15.2	99.6
					84.1							

(*a*.) Ore over-2-mesh after roll-crushing is in pieces averaging 3/4" in size.

(*b*.) Material treated is over-2-mesh ore from *a*; it consists of tabular pieces about 3/16" thick and 5/8" long and broad.

(*c*.) Material treated is over-2-mesh ore from *b*.

(*d*.) Material treated is over-2-mesh ore from *c* and 2–6 ore from *a*, *b*, *c*, together with 64 pounds of the 2–6 mesh class derived from other work. Products coarser than 6-mesh are pieces not over 1/20" thick, but flat and wide.

(*e*.) Material treated is 2–6 ore from *d*. The two coarsest products exhibit very clearly the lamellar fracture of the rock.

(*f*.) Material treated is 2–6 ore from *e*.

Crushing Test 1.—A small lot of hand-broken ore, put through a jaw-crusher set at 1/2-inch and then carefully examined and jigged, showed that no considerable proportion of magnetite occurred separated from the gangue in any size coarser than 6-mesh. In this trial-test 53 per cent. of all the ore was rejected by a 6-mesh

screen, while 17 per cent. passed through a 30-mesh screen. Such a large proportion of waste fines resulting from comparatively coarse crushing was taken as a caution to proceed by very gradual, successive size reductions in attempting to bring all the rock down to a 6-mesh size without producing an excessive amount of waste fines.

TABLE III.

RAW ORE. Hand-broken to $1\frac{1}{2}''$ size.	Pounds of Ore Crushed	Size of Products in Meshes per Inch. Weights in per cent.										Total Products in per cent.
		Over 2	2-4	4-6	6-8	8-10	10-12	12-16	16-20	20-35	Thro' 35	
a. Thro' Rolls at $\frac{1}{16}''$	242	70.7	11.1	4.2	1.5	2.1		2.5		2.6	4.5	99.2
b. " " $\frac{6}{16}''$	171	64.2	21.9	6.1	1.6	1.8		1.9		1.8	2.9	102.2
c. " " $\frac{3}{16}''$	273.5	0.2	28.1	37.3	7.3	7.1		6.5		4.7	7.0	98.2
d. " (scant) $\frac{1}{16}''$	218	—	—	0.5	2.9	10.6		39.7		21.4	24.8	99.9
	359.5	—	—	0.3	9.1	8.5	5.4	11.0	20.6	19.1	24.8	98.8
					73.7							

(*a.*) Over-2-mesh ore after crushing consists of pieces varying from just over $\frac{1}{2}''$ diameter to pieces $2''$ long by $1\frac{1}{2}''$ wide by $\frac{5}{8}''$ thick. All the 2–4 ore consists also of thin flat pieces.

(*b.*) Material treated is over-2-mesh ore from *a*. The over-2-mesh product after crushing is of $\frac{5}{8}''$ to $\frac{3}{4}''$ size.

(*c.*) Material treated is over-2-mesh ore from *b*, and 2–4 ore from *a*, *b*, together with $99\frac{1}{4}$ pounds 2–4 ore not otherwise tabulated. The 2–6 mesh products are all thin slivers.

(*d.*) Material treated is all the ore coarser than 4-mesh from *c*, and 4–6 ore from *a*, *b*, *c*, besides $18\frac{1}{4}$ pounds of this same size derived from other work.

Crushing Test 2.—Accordingly another ore lot was broken down by hand to $2\frac{1}{2}$-inch pieces and fed to a small Dodge breaker set at $1\frac{3}{16}''$ when open, or $1''$ when closed; the crushed rock was sized, and all material refused by a 2-mesh screen, amounting to 274 pounds or 76.5 per cent of the entire lot, and consisting largely of $1\frac{1}{2}$-inch pieces, was passed through $18''$ rolls set to $\frac{11}{16}''$ and sized; the over-sized classes (coarser than 6-mesh) were crushed down and re-sized; these operations were repeated a number of times as seen by Table II.

It will be observed that, although practically all the ore passed a 6-mesh screen, only 12.2 per cent of waste fines were produced. This figure is rather too favorable, and should be nearer 18 per cent., as 64 pounds of 2–6 mesh ore were added in the fourth pass, as appears above, without the fines produced in breaking this extra lot down to that size; but even so, when compared with the results of the first test, there is a marked improvement. Further tests were required to determine whether this record could be maintained with fewer crushing passes.

Crushing Test 3.—The material treated was 242 pounds of hand-broken ore, 1⅝ to 1¾ inch in size, containing a trifling proportion of fines. The result of four successive crushing passes through 18-inch rolls is exhibited in Table III. In the third pass, *c*, 99¼ pounds of 2–4 ore, and in the fourth pass, *d*, 18¼ pounds of 4–6 ore were added to the main lot, making the final figure appear rather too favorable for the same reason as given in the preceding case.

Compared with the results of Test (2) the more rapid size reduction of this last test yields only 73.7 per cent. of "jigging ore" as against 84 per cent. before obtained; while the waste fines are increased from 15.2 per cent. to nearly 25 per cent. The large proportion of fines from the last pass of Test (3) indicates clearly that the reduction from $\frac{3}{16}''$ to a scant $\frac{1}{16}''$ was too rapid under the circumstances. Altogether the results of this test were regarded as too unpromising to warrant further experiments at rapid reduction of the raw ore. Though the rock is not refractory, its more or less gneissic character gives it a lamellar fracture; many of the crushed pieces are thin, but broad and flat, which explains the large percentages of oversized products obtained even when the rolls are closely set (see Tables II. and III.). To determine whether an improvement in this respect could be effected by calcining was the object of the next test.

Crushing Test 4.—Two hundred pounds of ore, partly in small lumps and partly broken by hand to 1½-inch pieces, were heated in a reverberatory furnace to incipient redness, and then crushed and sized as in Table IV. Each lump of ore appeared to be calcined to a depth of about ⅝", but the kernels showed no evidence of oxidation. All the ore, however, proved to be extremely friable, crushing with greatest ease. The products still exhibited the lamellar fracture of the rock, though not to the same degree as the raw ore.

TABLE IV.

CALCINED ORE. "Small Lump" and $1\frac{1}{2}''$ size.	Pounds of Ore Crushed.	Size of Products in Meshes per Inch. Weights in per cent.										Total Products in per cent.
		Over 2	2-4	4-6	6-8	8-10	10-12	12-16	16-20	20-35	Thro' 35	
a. Thro' Dodge at $1\frac{3}{4}''$	230	74.8	6.1	4.5	2.0	3 0		3.8		2.6	3.3	100.1
b. " Rolls at $1\frac{1}{8}''$	172	46.2	17.6	9 4	3.5	5.9		6.3		4.2	4.7	97.8
c. " " $\frac{6}{16}''$	123.5	5.0	41.9	20.8	6.2	8.5		8.7		5.0	6.2	102.3
d. " " $\frac{4}{16}''$	110.5	—	0.8	6.3	16.7	32.1		21.3		11.3	10.9	99.4
e. " " $\frac{2}{16}''$	7	—	—	—	9.5	25.0		35.7		14.3	14.3	98.8
	230	—	—	—	16.3	16.2	11.6	8.4	15.7	14.3	15.7	98.2
					82.5							

(*a*.) Dodge crusher set at $1\frac{3}{4}''$ open, or $1\frac{5}{8}''$ closed. The small proportion of fines is explained by the fact that two-thirds of the ore had been hand-broken, so that the comparative calcining of small and large pieces might be observed; the hand-broken material dropped through the crusher without being caught by the jaws.

(*b*.) Material treated is over-2-mesh ore from *a*. The 2–6 sizes still present an unmistakable gneissic appearance.

(*c*.) Material treated is over-2-mesh ore from *b*, and 2–4 ore from *a*, *b*.

(*d*.) Material treated is all the ore coarser than 4-mesh from *c*, and all 4–6 ore from *a*, *b*, *c*.

(*e*.) Material treated is all the ore coarser than 6-mesh from *d*. The setting of rolls was not altered from that of the preceding pass, and in continuous work this small ore lot would be returned to that pass.

By this test 82.5 per cent. of jigging ore was produced with a loss of only 15.7 per cent. of waste fines. These figures are nearly as good as those of Test (2), while from an economical standpoint the last result is far more satisfactory, since it has been obtained with practically but three successive roll passes instead of six. The comparatively thorough disintegration of the ore in the earlier passes, as observed in Table IV., naturally suggested in the next experiment an attempt at more rapid reduction of the calcined ore, though this same method had proved unsatisfactory in working upon raw ore.

Crushing Test 5.—Two hundred pounds of ore in "small lump"

size—pieces averaging $6'' \times 4'' \times 2\frac{1}{2}''$ — were calcined as in Test (4), but none of the lumps were hand-broken before calcination. The kernels remained apparently unaltered, though all the ore proved, as before, to be very friable. The rock was crushed by comparatively rapid reduction, as seen in Table V.

TABLE V.

CALCINED ORE. "Small Lump" size.	Pounds of Ore Crushed.	Size of Products in Meshes per Inch. Weight in per cent.										Total Products in per cent.
		Over 2	2-4	4-6	6-8	8-10	10-12	12-16	16-20	20-35	Thro' 35	
a. Thro' Dodge at $1\frac{3}{4}''$	187	70.9	6.0	4.1	1.7	3.6		4.8		3.3	4.3	98.7
b. " Rolls at $\frac{3}{4}''$	143.8	7.7	31.0	17.8	6.4	10.8		11.5		7.5	7.5	100.2
c. " " $\frac{3}{4}''$	13.5	31.5	31.5	11.1	3.7	5.6		5.6		5.6	3.7	98.8
d. " " $\frac{3}{4}''$	87.8	—	1.4	33.3	18.2	19.6		13.9		5.1	10.2	101.7
e. " (true) $\frac{3}{4}''$	29.3	—	—	9.4	13.6	39.3		22.2		9.4	8.5	102.4
	187	—	—	1.5	17.6	20.4	7.6	9.7	14.3	13.3	16.4	100.8
						82.9						

(*a*.) Crusher set at $1\frac{3}{4}''$ when open, or $1\frac{3}{8}''$ closed. The over-2-mesh product consists largely of pieces $1\frac{1}{2}$ to $2\frac{1}{2}$ inches long and wide, and 1 to $1\frac{1}{2}$ inches thick.

(*b*.) Material treated is all the ore from *a* refused by a 4-mesh screen. The resulting product over-2-mesh is decidedly lamellar.

(*c*.) Material treated is the over-2-mesh ore from *b*, with the idea that in practice this lot would be returned to the preceding roll pass. It consists of thin flat pieces, which accounts for the large proportion, 74.1 per cent., of over-sized product formed, showing that this lot *c* ought rather to be fed to the next finer roll pass.

(*d*.) Material treated is the over-2-mesh ore from *c*, all 2–4 ore from *b*, *c*, and 4–6 ore from *a*, *b*, *c*. After getting through with the crushing it was ascertained that the rolls had not been set true; at one side their faces were nearly $\frac{1}{16}''$ apart; this explains the large proportion of over-sized product, 34.7 per cent. (compare Table IV., *d*), and makes the next pass necessary.

(*e*.) Material treated is 2–6 ore from *d*. The resulting 4–6 product consists of very thin pieces.

The table shows that 83 per cent. of jigging ore is obtained at a cost of $16\frac{1}{2}$ per cent. of waste fines, with virtually only two roll passes (see notes *c*, *d*), and one rock-breaker pass. These fig-

ures are substantially the same as those of Test (4); the last experiment seems, therefore, to warrant the inference that results may be attained in rapid reduction of the calcined ore, which were altogether beyond reach in working upon the raw ore. With better calcination a still further improvement might reasonably be expected.

Conclusions upon Crushing.—From the foregoing crushing and sizing tests the following conclusions with regard to the treatment of the ore were drawn:

1. The ore should be calcined sufficiently to make it quite friable and reduce very perceptibly the tendency to lamellar fracture. The advantages of calcining are: (*a*), making the ore so friable that it breaks up thoroughly in comparatively coarse passes of the crushing machinery and in this way diminishes the production of waste fines; (*b*), increasing the friability of the gangue in relatively larger measure than that of the magnetite and so raising the percentage of iron in the coarser jigging sizes, as shown by Table VI.; (*c*), increasing the capacity of the crushing machinery

TABLE VI.

Mesh.	6-8	8-10	10-12	12-16	16-20	20-35
Raw ore, percentage of iron.....	43.66	44.25	46.28	46.42	—	—
Calcined ore, " "	50.19	50.19	49.03	47.37	40.56	32.50

at least two- or three-fold; (*d*), correspondingly reducing the wear of the crushing machinery per ton of ore treated; (*e*), improving the shape of the ore grains for jigging—there being fewer thin flat pieces produced than in crushing raw ore; (*f*), reducing the percentage of sulphur by more or less complete oxidation of any pyrites present.

2. The calcined ore should be put through a large rock-breaker, set to about two inches when closed, and then through 40- or 42-inch rolls, set to one-eighth inch, and capable of taking hold of the coarsely broken rock. The over-sized ore (coarser than 6-mesh) should be put through a second pair of rolls, set to one-eighth inch; the small lot of ore which is refused by a 6-mesh screen after passing the second rolls should be returned to that pass.

By crushing calcined ore in this manner, 83 to 85 per cent. of

the total ore will be obtained in jigging sizes at a loss of waste fines never exceeding in practice 16 per cent. An analysis of an average sample of waste fines yielded 31.4 per cent. of metallic iron, which is less than three-fourths of the average iron contents of the ore, indicating, therefore, that in fine crushing the gangue breaks up more readily than the magnetite. Hence the production of 16 per cent. of waste fines means a loss *not* of 16 per cent., but only of 12 per cent. of the iron in the ore. As the latter contains according to the analyses of three separate samples an average of 44 per cent. of iron, the actual loss by the production of fines in crushing will be 12 per cent. of 44, or 5.3 units of iron. This figure is a maximum, and it should not be difficult in good practice to keep within a lower limit.

Jigging Tests.—The classified ore obtained in the foregoing operations was sorted on a small two-compartment, fine-grain Hartz jig, with sieves measuring $7'' \times 18''$. A mineral-bed of magnetite, usually one size coarser than the particular ore-class treated, was used upon each jig sieve. The heads and middlings passed through the sieves into the first and second hutches respectively, and the tailings overflowed the lower dam as usual. The products from each test were dried, weighed and carefully sampled for analysis. It was found by special determination that all the phosphorus of the ore occurred in the gangue, and this facilitated much of the analytical work. In order to obtain a fair quantity—say 65 to 100 pounds—of ore for each test, it was found necessary in several cases to mix together the raw and partially calcined ore of the same sizes. This practice, and reference to Table VI., will account for the varying percentages of iron in the undressed ore as hereinafter given in Table VII.

The aim with which the tests were begun was to produce a Bessemer concentrate (Fe, 60 per cent. and over; P, 0.06 per cent. or less), and at the same time make tailings which would run sufficiently low in iron to permit of their being discarded without great loss. Four successive tests on 6, 8 and 10-mesh raw ore seemed to demonstrate the futility of any such attempt. The work was slowly and cautiously done on the first sieve of the jig, but with the invariable result that a 60–62 per cent. concentrate could not be produced without a loss of 21–25 per cent. of iron in the tailings. With such a showing it was evident that, at least in its coarser sizes, the ore could not be satisfactorily dressed without forming a

middling product. The intimate mixture of the ore constituents, when considered in its bearing on the positive requirement for keeping to coarse concentrates, debarred the simplest solution of the dressing problem—*i.e.*, the direct separation of magnetite (specific gravity 5) from gangue (specific gravity 2.7–3.2). The experiments point to far more delicate work—namely, the separation of a high-grade magnetite, carrying not more than 0.06 per cent. of phosphorus, from a leaner product probably higher in phosphorus, which in turn has to be sufficiently freed from gangue to raise it to a marketable grade. Accordingly the aim of all further work was to produce for heads, a Bessemer concentrate; for middlings, a Foundry concentrate; and for tails, just as poor a product as possible.

One of the above-mentioned tests was made with 8–12 mesh ore. A close examination of the tailings revealed the presence not only of "mixed grains" (part mineral and part gangue) but also of many particles of 10–12 mesh magnetite which furnished additional argument, if any were needed, for the necessity of close sizing. The next eight tests on 6, 8, 10, 12 and 16-mesh ore served to determine the most favorable conditions for working the small jig on each of the several ore sizes. These tests were followed up by a second series, the results of which are given in Table VII.

TABLE VII.

	a.		*b.*		*c.*		*d.*		*e.*		*f.*	
Mesh.....	6-8		8-10		10-12		12-16		16-20		20-35	
Condition.....	Calcined.		Raw & Calc.		Raw & Calc		Raw & Calc.		Calcined.		Calcined.	
	Fe	P	Fe	P	Fe	P	Fe	P	Fe	P	Fe	P
Ore.....	50.41	0.103	47.73	0.082	45.83	0.087	46.38	0.068	40.56	0.078	32.50	0.105
Heads.....	64.54	0.058	62.57	0.077	64.41	0.063	63.33	0.060	64 17	0.058	63.66	0.040
Middlings.....	55.82	0.098	51.44	0.094	57.58	0.080	58.47	0.072	49.84	0.093	43 25	0.157
Tails.....	12.82	0.110	16.31	—	18.17	—	12.67	0.058	5.95	0.063	4.86	—

(*a.*) 89 pounds of ore jigged. Proportion of heads to middlings 30.4 to 69.6.
(*b.*) 171 " " " " " 36.2 " 63.8.
(*c.*) 96 " " " " " 38.0 " 62.0.
(*d.*) 63 " " " " " 44.8 " 55.2.
(*e.*) 62 " " " " " 47.0 " 53.0.
(*f.*) 55 " " " " " 63.8 " 36.2.

An examination of this record shows the possibility of obtaining

by jigging from all the calcined ore between 6 and 35 mesh the following products:

	Iron.	Phosphorus.
Heads	63 per cent. and over.	0.063 per cent or less.
Middlings	55 " "	0.095 " "
Tails	16 " "	——

These figures are not averages computed from the table, but they represent results which are easily within reach of a laboratory jig. In practice, with large machines, heads running 64 per cent. iron and not more than 0.055 per cent. phosphorus ought to be obtained without difficulty from the calcined ore. The advantage of calcining in thereby enriching the coarser ore sizes has already been pointed out. It is the coarse sizes which are least easy to treat because of the large proportion of mixed grains present; the enrichment occurs, therefore, just where it proves of greatest benefit. Tests *b* and *c* would probably make a still better showing than they do if the respective ore classes had been composed of calcined stuff only.

Phosphorus is seen by Table VII. to concentrate in the middlings, which is not surprising as apatite is among the specifically heaviest of the gangue minerals, but the fact appears to indicate also an intimate association of iron and phosphorus in the "mixed grains" of the foundry concentrate. The presence or absence of sulphur was disregarded in the tests, as the amount of sulphur reported in the ore had no economic importance.

As previously observed, the jig products of each test were weighed (dry) to check results, but it would obviously be wrong to deduce from these weights the quantities of concentrates and tailings obtainable in practice. The partly jigged ore upon the sieves is a disturbing factor of appreciable magnitude in the laboratory results. It cannot be eliminated by simple subtraction. The quantity of concentrates—heads as well as middlings—formed in an experimental test with a small lot of ore evidently depends in large measure on the ratio of the total weight of the test lot to that required for filling the sieves. It is only the comparative proportions, therefore, of these two grades of concentrates, obtained in the laboratory, which deserve attention; with due reservation

they serve to approximate the quantitative relation between heads and middlings in practice. In seeking to determine a fair average of these proportions, the gradually increasing ratio between the successively finer products of the experimental heads and middlings cannot escape notice. The change is evidently due to the smaller percentage of "mixed grains" in the finer, more thoroughly disintegrated ore classes. Figuring upon the results of Table V. it appears that 15.6 per cent. of all the jigging ore would in practice be 20–35 mesh stuff. This alone, as can readily be seen, would raise the proportionate production of heads appreciably; in the present case, however, it was thought preferable to attach but little weight to this favoring circumstance, and rather adopt figures which were well within the mean of results obtained with the coarser sizes. A proportion of heads 36 per cent., to middlings 64 per cent. was taken as a conservative basis for computing practical results.

Conclusions Upon Jigging.—The data for estimating the yield per gross ton of ore may be recapitulated as follows:

	Per Cent.
Raw ore averages,	44 iron
Waste fines,	16 ore
Heads average,	63 iron
Middlings "	55 "
Tails "	16 "
Percentage proportion of heads to middlings,	36 to 64

By sifting out the poor waste fines produced in crushing, the raw jigging ore is enriched to 46 per cent. iron. The additional enrichment of the coarser sizes by calcining is balanced by the impoverishment of the finer classes, and hence does not enter into the calculation. One gross ton of mine ore therefore yields:

Waste fines,	359 lbs.,	or 16.0 per cent.,	carrying	178 lbs.	iron.
Bessemer concentrate,	484 "	21.6 "	"	305	"
Foundry concentrate,	860 "	38.4 "	"	474	"
Waste tails,	537 "	24.0 "	"	86	"
	2240	100.0		983	
Unaccounted through discarding fractions,				2	"
		44 per cent. of 2240 =		985	"

A ton of concentrates (Bessemer and Foundry) would by these figures be obtained from 3730 pounds, or 1.66 tons of ore.

The limited quantity of material available for the foregoing experiments precludes any generalization upon the results; but as these will at least prove suggestive they have not been considered unworthy of record.

THE DISTILLATION OF PINE WOOD IN THE SOUTH.

BY FRANKLIN S. CLARK, E.M., PH.D.

THE rapid advance made within recent years in the Southern States toward industrial development, has called forth numerous accounts of chemical and mechanical industries which are fast removing from this section of the country its purely agricultural aspect.

While the coast region has produced rice, cotton and phosphate in such proportions as to render these names inseparable from those of our Atlantic coast States in the South, the interior country, thickly wooded with pine, has yielded to commerce the yellow pine lumber and naval stores, each of which has found such extensive application as to make the forests of long-leaved pine the source of two of the largest industries in the South.

The value of this wood for distillation has also received recognition, and the manufacture of wood products from long-leaved pine has, within the past few years received such an impetus that the process of destructive distillation, as applied to wood, is now an established and growing industry in the Southern States. As carried on in the North this industry has had for its main products wood alcohol, acetic acid and charcoal, the harder species of wood being subjected to distillation, in view of the high percentage of wood alcohol and acetic acid contained among the products of distillation.

The South, with its extensive forests of pine, covering the greater part of the country near the seaboard, made in earlier years but slow progress in the distillation of wood, the forests being, however, much prized for their lumber value and their contents of turpentine or "crude gum."

They were considered to have fulfilled their purpose after having been tapped for turpentine, and were then cut for fuel or to make tar and charcoal, or else left standing, with the risk of feeding fores[t]

fires, which are damaging not only to the trees themselves but to the succeeding growth. When they are left standing there is a tendency to resinify, which increases their value, both for fuel and for the retorting process. The tapping process, however, is considered to decrease their value as lumber.

With the growth of railroads in the Southern States and the necessity for preserving the timber of these roads, as well as the wharves and other wooden structures in the coast cities, considerable incentive has been given to the application of creosoting materials and processes, and, as a result, attention has been called to the pine forests as a source from which creosote could be procured.

Works have been established and the manufacture of creosote oil from wood has been carried on to supply an increasing demand.

The southern works, unlike those of the North, endeavor to procure from the wood the greatest yield of oily products, those already mentioned as forming the basis of the hard wood industry being secondary, though produced in marketable condition.

The main features of the dry or destructive distillation are found in the entire exclusion of air, after the operation is once under way, and the continued application of external heat, resulting thus in a large yield of condensable products, but in the maximum consumption of fuel, and differing essentially from the ordinary process of charcoal burning, in that the latter, from a calorific point of view, is self-sustaining but yields an inconsiderable quantity of liquid products. The various modifications of these two systems of charring wood form such a continuous chain that from a constructive point of view it is difficult in many cases to distinguish between them.

The present knowledge of the effect of heat upon wood secluded from the air is largely hypothetical, although this subject has an important bearing upon the nature and amount of the products of distillation. Wood, being of a complex composition, is easily decomposed by heat, and more simple bodies result; but to what extent these latter owe their existence to the dissociation and recombination of the elementary constituents of the wood, is a question still open to discussion. In the case of resinous woods it is quite likely that some of the substances resulting from the distillation are educts, having previously existed in the wood,

though, perhaps, in a somewhat modified condition, while some writers take the view that even the phenoloid bodies were more or less ready formed. By some this view has been extended to the methylic alcohol and acetic acid, the assumption being made that they form an unstable compound with some base or other constituent of the wood. It is supposed that this compound is a result of the plant growth and gives to each species its physical characteristics, such as color, density, elasticity, etc.

The formation of acetic and other salts from wood directly, as has been asserted, would not, however, warrant the assumption that these acids are identical with those produced by distillation, for the small amount of salt formed may be due to the inconsiderable amount of acid in the sap.

The most plausible view of the destructive distillation is, that most of the resulting liquids and gases are products and owe their formation to the rearrangement of the three important wood elements: carbon, hydrogen and oxygen. These elements existing in the wood in different proportions as the operation advances, in consequence of their unequal stability under heat, present the conditions necessary for the formation of an extensive series of compounds, modified to a greater or less degree, according to the particular construction of the apparatus and the regulation of the heat.

The large amount of water in the product, in excess of that held mechanically in the wood previous to the distillation, is explained by assuming that the hydrogen and oxygen, forming about fifty per cent. of the dry wood, and contained in nearly the proportion to form water, combine as soon as the heat is raised to a point which renders their combination in the woody fibre unstable.

With the more complex distillate, any assumption as to its formation is more uncertain, since there is a wider scope for speculation as to the different possible combinations.

Besides the direct combination from the wood there are other causes which influence the formation of products. The retort itself may be so constructed that a part of the product is decomposed in the interior, some of the products being subject to decomposition at the temperature of their formation, and especially if in contact with the hot plates of the apparatus.

The action of the hot charcoal, as well as the reactions between the vaporous products themselves, leads to the formation of new bodies.

Acetic acid, one of the earlier products of the distillation, has been considered as formed from several different reactions. One of these is by the abstraction of water (as chemically combined), from cellulose, thus:

$$2C_6H_{10}O_5 - H_2O = 3C_4H_6O_3 \text{ (anhydrous acid).}$$

Another hypothesis for its formation is by the oxidation of ethene:

$$2C_2H_4 + O_4 = 2C_2H_4O_2 \text{ (hydrated).}$$

In both these instances oxygen really effects the formation, and probably also plays an important part in the formation of some of the most complex bodies of the distillate.

By the effect of heat or the reactions between the products themselves, Dr. Bersch accounts for the formation of most of the wood products, as is illustrated in the following equations:

Methylic Alcohol—$CH_4 + CO_2 = CH_4O + CO$.
Acetone—$2(C_2H_4O_2) + \text{heat} = C_3H_6O + CO_2 + H_2O$.
Naphthalene—$10CH_4 + \text{heat} = C_{10}H_8 + H_{32}$.
Propylene—$2CH_4 + CO = C_3H_6 + H_2O$.
Acetylene—$4C_2H_4 = 2C_2H_2 + 3CH_4 + C$.
Hydrogen—$CH_4 + \text{heat} = H_4 + C$.
Ammonia—$H_3 + N \text{ (from sap)} = NH_3$.
Methyl amine—$CH_4O + NH_3 = CH_5N + H_2O$.
Di-methyl acetate—$2(CH_4O) + C_2H_4O_2 = C_4H_{10}O_2 + H_2O + O$.
Aldehyde—$C_2H_4O_2 + CO = C_2H_4O + CO_2$.

Various other reactions are capable of forming the above constituents of the distillate and many others.

The chemical agencies, such as the reactions above, are beyond the control of the wood distiller, but the regulation of the heat and the construction of the distilling apparatus, which elements are of vital importance to a proper distillation, being under control, may be varied in such a manner as to best accomplish the particular end in view.

We therefore find, in the different wood distilling works, apparatus and methods quite dissimilar and designed in each instance to effect a more perfect purification or an increased output of some particular product, for it is especially true in this industry that any attempt to make all the products of superior quality results in an average inferiority.

So far as the general chemical combinations are concerned, the process is substantially the same in the different works.

During the first hours of the application of heat the products contain an excess of oxygen, combined with hydrogen, or carbon, or both. Thus, among the gaseous products carbonic acid preponderates at first, but as the operation progresses and the percentage of oxygen in the wood becomes less, the carbon combines with a smaller quantity, and carbon monoxide makes its way from the retort in small but increasing quantity until it is found in excess, and is itself succeeded by the hydrocarbon gases, methane, ethane, and ethine. With these gases combination occurs as before, the most saturated marsh-gas or methane appearing at the less elevated temperatures, while, as the temperature rises and the percentage of hydrogen in the wood grows less, the lower hydrocarbons, ethene and ethine, are found among the permanent gases.

At still higher temperatures the hydrocarbons are subject to decomposition, accompanied by a deposition of fine carbon on the sides of the retort and an evolution of free hydrogen.

Among condensable products will first be found water, resulting from the combination of hydrogen and oxygen from the wood structure, followed by acetic and other fatty acids, methylic alcohol, phenoloid bodies, and finally at a high temperature by the heavy hydrocarbons, so invaluable in the creosoting process.

The Wood.

The wood subjected to distillation in the southern works is the long-leaved pine (*Pinus Palustris*), well known as the source of commercial turpentine.

It is known locally under several other names (yellow, southern, pitch and Georgia pine), but its long leaf, being a characteristic feature of the tree, most fittingly names it. This tree, though much thinned in particular localities on account of the demand for timber, forms an almost unbroken belt, parallel to the Atlantic and Gulf coast, stretching from Virginia, through the Carolinas and Georgia, into Florida, thence westward, through the Gulf states, into eastern Texas. Passing a short distance from the Atlantic coast, it is encountered more densely congregated the farther from the coast until the true pine belt is reached. Here it forms a continuous

forest, broken only where the swampy southern rivers intersect it. These rivers are usually bordered on each side with an extended swamp, in which the long-leaf pine is replaced by cypress trees and low tangled undergrowth. Emerging from these swamps to higher ground, the pines are again found as an unbroken forest. Near the coast the loblolly palmetto and oak take its place, while in the direction of the mountains, the long-leaved pine gradually merges into the short-leaved and various deciduous trees.

In the interior of the States, below the central part, there is an enormous supply of this wood, but the supply in proximity to the southern cities, where the distilling operations are carried on, is limited, and since it has most generally been cut near the rivers, it is procured from year to year at greater expense. The wood distiller is, however, not placed under the same disadvantage as the lumberman, since the large number of trees which have been tapped for turpentine are well suited, if not to be preferred, for the retorting process, while they are considered inferior for lumber.

The most unsuitable wood for distilling is green wood, since it gives a large yield of very weak pyroligneous acid, but a small proportion of oily products. A cord of this wood subjected to distillation gave only 50 per cent. of the yield of oily products usually obtained from the ordinary wood.

All the works that distil the long-leaved pine are in the Southern States (although to carry on the operation in the North is quite feasible), and usually in the cities of the coast, the wood being cut through the pine country and taken to the cities by transportation down the rivers. The erection of the retort plant in the forest has never been considered practicable on account of the permanent and extensive nature of the works and the necessity of limiting the choice of wood to the particular locality selected.

Location in the forest saves the transportation of 2225 pounds per cord of wood, representing gas, water, and charcoal, but if there is any sale for charcoal in the city it will easily pay the difference in transportation, and in such case would, of course, not be burned under the retort as fuel.

Distilling Apparatus.

The apparatus consists of the retort, with its setting and flue system, together with a condenser. Cast and wrought iron (or steel) are the only materials which have come into general use for

the retorts, wrought iron or steel being used in the southern works. Some works have used masonry kilns, but the process is not one of true destructive distillation, although it may have some advantages over the process as carried on in retorts. The low price of iron, together with its suitability to resist the heat and expansion and contraction consequent to the distillation, has sanctioned its general use, but it is a much disputed point among wood distillers as to the relative merits of cast and wrought iron. The former is probably preferable for small retorts, since in this case a good casting may be had at a moderate price, while, on the contrary, small wrought iron retorts tend to burn out quickly. With large retorts cast iron is more liable to flaws and becomes expensive. It may crack after several firings, but with wrought iron retorts properly encased, the duration, before patching becomes necessary, may be five years or longer.

The retort is preferably cylindrical and made very long compared to its diameter, the proportion of three to one being not too great. They are seldom made over seven or under three feet in diameter, but in length are made from five to thirty feet or more.

The common practice is to have a single retort encased in brickwork, and to effect the charging with wood and removal of charcoal by manual labor, although this part of the operation has in some of the works been accomplished in a more rational manner.

The retort is made of ¼-inch to ⅜-inch wrought iron or steel plates, the heavier metal being used where the apparatus is exposed to the greatest heat.

The flue system is of particular importance, for since the retort may be considered as empty so far as the effects of heat are concerned, it is necessary that the products of combustion should distribute their heat as equally as possible over the different portions of the cylinder, and in no case should there be a concentration of heat at any one part.

The furnace gases are usually made to pass under a fire-brick protecting arch as they leave the furnace, this arch being built under the retort as a protection against the direct action of the flame, which is especially destructive to wrought-iron cylinders when weighted down by a body which does not absorb the heat. The first heating is therefore due to radiation from the upper surface of the arch, and the radiant heat is more the longer the arch and superimposed retort.

In passing from the arch the products of combustion come in direct contact with the metal, and it is this heating that deteriorates both the retort and the products of distillation.

It will therefore be found that the shorter the retort and arch, the more quickly will the former be affected by the heat, while an excessive decomposition (or "burning") of the wood will occur at low temperatures, with a consequent deterioration of the product.

The passage of the products of combustion from the arch, the back connection, and the return flue system, are different in different works.

In some cases the gases escape through perforated brickwork at the side of the arch, near its extreme inner end; in others, through perforated brickwork at the end, and in some cases the end of the arch is left entirely open.

In some of the flue systems, the hot gases, after leaving the arch, are returned immediately to the front portion of the apparatus by a flue formed between the retort above, the arch below, and the two side walls which sustain the weight of the retort. From the front of the apparatus they pass upward through a vertical flue and escape from the stack at the front of the apparatus, or again pass to the rear wall through a flue formed by the upper half of the retort and a covering arch. This flue system is especially injurious in its effect, both to the retort and the product of combustion, for since the retort extends beyond the arch in both directions, passing through the front and rear walls, it receives the direct heat from the flame just as the latter leaves the rear end of the arch and passes upward.

The arch, on account of its semicircular form, delivers to the flue directly above, a mass of hot gas which is inverse in shape to the flue which receives it. There will therefore tend to be at the entrance to the flue, in the contracted portion under the lowest part of the retort, a concentration of heat, before the gases can expand into the chamber space. In practice it will be found that the retort will first burn out along its lowest line and in this contracted portion, or else a short distance toward the rear between the end of the arch and the rear wall, these two being the most susceptible parts of the apparatus as here described. The ordinary horizontal flue system just described is ill suited for retorts on account also of the unequal heating of the different parts of the cylinder. The hot gases returning to the front wall by pass-

ing through the flue below the retort, unite their heat with the radiated heat of the arch, all of which is directed against the lower half of the cylinder, while the gases which alone heat the upper part of the cylinder are at this part of their course comparatively cool. The result is an excessive heating of the lower part of the retort and an insufficient heating of its upper portion, with a consequent deterioration of both apparatus and vaporous products.

The rear, upper, and lower portions especially are subjected to the extremes of heat in this flue system; hence there is an unequal expansion and contraction, and as they are rigidly connected, though separated by a non-conducting partition at the mid line of the retort, there results a buckling of the lower portion and a tearing of the plates along the mid horizontal line of rivets.

The effect upon the vaporous products is a condensation in the upper part of the cylinder, and a decomposition of the liquified products as soon as they fall upon the hot plates at the bottom.

Another flue construction, in operation in the South, and one which is much less damaging to the apparatus and contained vapors, allows the gaseous products from the furnace to escape, as already mentioned, at the side of the arch, passing thence to a flue of uniform diameter and concentric with the retort itself.

In consequence of a series of baffle plates, extending vertically from the protecting arch upward and from the covering arch above the retort downward, the gases are made to move around the cylinder from its lower portion to the upper, thence horizontally forward until meeting a baffle plate, thence downward to the lower portion again, along which they move horizontally until striking another baffle plate, which causes them to repeat their vertical course.

They thus pass from the rear portion of the apparatus to the front by a zigzag course, becoming reheated each time they pass downward and come in contact with the hot arch, which is more heated toward the front of the apparatus, where the gases are themselves comparatively cool. This system favors a more uniform heating of the apparatus above and below and at both ends, while the flue, being of uniform size, and the products of combustion striking the retort tangentially as they leave the arch, the tendency is to lessen the wear and tear on the metal.

A burning through of any of the plates is most likely to take place where they have been buckled or warped transverse to the passage of the flame, for here the resistance is greatest. Such an accident is immediately followed by the wood vapors of the distillation igniting and burning violently at the rent, the temperature passing considerably beyond that usually carried.

The hanging of the retort is effected by the ordinary series of side lugs resting upon plates, which distribute the weight to the brickwork of the side walls..

The door through which the charging is effected is hung on hinges attached to a cast-iron ring riveted to the front end of the retort. The ring is made with a flange concentric with the retort, thus offering a surface against which the door may abut when swung in place. By the insertion of an asbestos rope gasket between the surfaces of the door and flange, and driving the former tight by wedges, passing through eye castings attached to the ring, a perfectly air- and vapor-tight joint is made.

The condenser connects with a cast-iron goose-neck, passing usually from the upper portion of the apparatus, and is made of copper in the form of a coil, or of flanged cast-iron pipe.

The former construction is in use in the pine-wood works, where, in consequence of the fluid and solvent nature of the product, there is no danger of an obstruction of the condenser. In the hard-wood works the tarry materials are very viscous, and the condenser is therefore made in separate sections, in order that it may, if necessary, be taken apart and cleaned. The condenser terminates in a trap which allows the permanent gases to separate from the liquid distillate; the former passing upward to the scrubber, while the latter flow to the receiver. One or two receivers are used, according as the distillate is or is not separated into two portions, constituting the light, first running, and the heavier products which pass over at more elevated temperatures.

The first running consists of a light oil which passes over with and floats upon a large quantity of water, and in order to collect the oily product and allow the water to run to waste, a receiver is used, constructed upon the Florentine flask principle. To hold all the light oil from ten cords of wood an ordinary one hundred and fifty gallon wooden tank, provided with a pipe leading from its lowest portion to near the top, is sufficient, for although the oily and aqueous distillate will be far in excess of this capacity, the aqueous

portion forming the lower layer in the receiver will pass continually from the tank through the upright exit pipe, the oily product meanwhile augmenting until the receptacle is filled.

The second receiver is designed to accommodate by far the largest part of the distillate, and that which tends to corrode metals.

The most suitable material for its construction is masonry or wrought iron; the former not being affected by the pyroligneous acid, and making the best receiver if secured against cracks. Wrought iron is but slightly affected by pyroligneous acid mechanically mixed with the pine oil, and, therefore, if the distillate is not left long enough in the receptacle for a complete separation of the acid from the oil, a wrought-iron tank may be used to hold the crude product without any considerable formation of pyrolignite of iron. Wooden tanks lined with lead are rendered useless in a short time on account of the rapid action of the crude acid upon lead, the sheets of the latter becoming as thin as paper.

Operating the Apparatus.

Since the procuring of oily products is the main object of the process, the retort is charged with the most resinous pine obtainable, comparatively free from water, and preferably of a deep red section.

The fuel employed to carry on the process is the gas from the retort itself, together with charcoal or wood, the latter being used whenever there is a market for charcoal.

Gaseous fuel is not available in the early stages of the operation on account of the large percentage of carbon dioxide present. This tending to smother the fire, the gases generated by the distillation are therefore allowed to escape, until by the application of a light they burn with a blue flame due to the presence of carbon monoxide. At this part of the process they are directed into the chamber space under the arch, and form not an inconsiderable part of the fuel during the subsequent part of the distillation, at times giving an excess of heat and rendering a gas-holder desirable. The removal of carbon dioxide by lime-water is inexpedient, except in gas manufacture, but the conversion of this gas into the monoxide by hot charcoal or heated pipes is feasible.

At the commencement of the distillation firing is carried on with solid fuel, and after 2¾ to 3¾ hours, according to the regu-

lation of heat, the first distillate of light oil and water will flow from the trap. The temperature at which the first running passes over varies between 350° and 450° F., depending upon the wood and regulation of the heat, references here being to a one-cord retort. The first aqueous distillate is of a green tinge, and tests 1½°–2° Tw. (1.0075 to 1.010 sp. gr.), both the color and test being due to the presence of copper washed out from the coil.

After a few moments running it becomes clear, and the hydrometer sinks to the zero mark, at which it floats during the first hours of the distillation, and until the presence of acetic acid in the distillate raises the specific gravity. The hydrometer readings are to be relied upon only after a titration of the distillate with standardized alkali. From the commencement of the distillation the aqueous distillate is accompanied by the light oil, which at first passes over with a specific gravity of 0.87 to 0.88, and of a yellow to deep red color when examined in small quantities. In large quantity it is red to black. As already mentioned, this oil augments as the operation continues, the water being allowed to run to waste so long as it contains no considerable amount of acetic acid. By running the water away at this stage of the distillation, much time and steam is saved in the subsequent treatment of the pyroligneous acid for wood alcohol and acetate of lime.

The gaseous products have at first a turpentine-like odor, but will extinguish a light applied at the delivery pipe. As the operation continues they become combustible, and burn with a blue flame, which becomes tinged with yellow as the temperature rises and the hydrocarbons pass over, becoming more illuminating as the end of the distillation is approached.

It is difficult to burn the gases by conducting them immediately to the furnace space, since the condensable hydrocarbons tend to decompose and coke in the delivery pipe. It is preferable to draw the gaseous products from the retorts by some form of exhauster, and force them through a scrubber, which removes the tarry materials to such an extent that the resulting gases will scarcely discolor white paper.

The effect of an exhauster is to remove the vaporous products quickly from the retort, thus making the distillation easier, and decreasing the tendency to decompose the products before they have been withdrawn from the retort. The gases, after passing

from the scrubber, are preferably passed through water in a closed tank, thus shutting off all direct communication between the furnace and retort, and preventing any explosion back of the water tank, should air get in the retort or pipes. The light oil passing over in the early part of the distillation is sometimes cut off arbitrarily at a specific gravity of 0.92, and used as a paint oil, or in other cases it is allowed to flow in with the other products in the larger receiver.

The purity of this oil will depend somewhat upon the construction of the apparatus, and the care with which complete decomposition of the wood has been avoided.

Hence during the first hours of the operation the temperature should be moderate, not exceeding 550° F., and gradually attained. With the most carefully regulated process decomposition will ensue, and creosotic bodies pass off into the light oil distillate, and thus, as the operation proceeds, the specific gravity will rise. The temperature of 550° F. may be attained after 12 to 15 hours.

When the aqueous distillate begins to show any considerable proportion of acetic acid, which usually happens after about 50 gallons of distillate have passed over, the aqueous liquid is run from the separating receptacle into the large receiver, or, if the light oil is not separated, all the product may be now run into this receiver. After a separation of a sufficient quantity of light product, a more thorough decomposition of the wood is effected by carrying the temperature to 600° F., and above, according to the quantity of flow at the trap. The sp. gr. of the oil will now rise quickly to about 0.98, and the true pyroligneous acid will pass over of a gradually increasing density and very turbid, on account of the mechanically contained oil. As the percentage of real acetic acid in the crude product increases the test will rise until it reaches 7° to 8° Tw., from which point it will gradually decrease in gravity. The oil also becomes heavier as the end of the distillation grows nearer.

During most of the process it floats on the acid and passes over in about one-half the quantity of the latter, but toward the close of the operation, when a temperature of 730° to 750° F. is reached, there will be but a slow separation of the two products, on account of their close sp. gr., and finally, as the oil is produced at a still higher temperature, it will sink under the acid, testing as

high as 9° Tw. toward the last of the operation. The proportion of heavy oil is at this period in excess of the acid.

In order to effect a thorough carbonization, and produce a charcoal tolerably free from oils, the operation must be concluded at as high a temperature as 1000° F., which temperature could be resisted only by the best steel plates. The general practice is to finish the operation at only 800° to 850° F., with a consequent production of poor charcoal, as may be seen from the following analysis:

Moisture.....3.41 per cent. Ash.....0.54 "	Carbon.....63.80 per cent. Volatile matter.....32.24 "

After each operation with a one-cord retort it requires 8 to 9 hours' cooling, in order to allow of the removal of the charcoal from the apparatus and recharging with wood.

The following 16 determinations, made with average quality long-leaved pine, will represent the yield from the ordinary apparatus. The average amount of wood distilled was 1⅛ cords:

Charge.	Wt. of Wood lbs.	Light Oil gals. 0.875—0.950 sp. gr.	Pine Oil. gals. 0.950—1.040 sp. gr.	Pyroligneous Acid. 4° Tw.—1.020 sp. gr.	Charcoal lbs.
1		12.33	81.	182.	1481
2	4526	12.	81.5	197.75	1619
3	4513	10.	82.	174.25	1440
4	4478	12.	82.	203.5	1515
5	4577	17.75	73.5	181.	1380
6	4444	13.	81.5	200.	
7	4621	13.75	62.	194.5	
8	4598	12.25	65.75	195.5	
9	4555	18.25	78.5	176.	
10	4429	13.5	65.25	193.	
11	4672	13.5	58.5	200.	
12	4816	13.5	76.5	192.5	1475
13	4874	17.	73.75	170.	1772
14	4585	13.	77.5	197.	1613
15	4400	14.25	55.75	138.5	1390
16	4505	14.25	81.	170.25	1430
Average for 1⅛ cords.	4573	13.8	73.5	185.	1511

The following table gives the liquid distillate in portions (approximately sixths), in the regular order of their passage from the retorts:

TOTAL LIQUID DISTILLATE IN PER CENT.

Portion.	Oily Product.	Acid Product.
1st portion	2.68 — .885 sp. gr.	14.56 — 0.000 sp. gr.
2d "	2.68 — .910 "	11.49 — 1.0075 "
3d "	5.55 — .990 "	12.26 — 1.025 "
4th "	5.93 — 1.010 "	11.11 — 1.030 "
5th "	6.13 — 1.0165 "	11.11 — 1.025 "
6th "	9.19 — 1.025 "	7.28 — 1.020 "
Total	32.16	67.81

YIELD OF MAIN PRODUCTS.

Acid 1.020 s. g.	1572 lbs.	34.37 per cent.
Oil	729 "	15.94 "
Charcoal	1511 "	33.04 "
Gas	761 "	16.64 "

THE CRUDE PRODUCTS.

At the termination of the process the entire product from the receiver is pumped to an elevated tank for the purpose of settling. This usually takes place in 24 hours, but it depends somewhat upon the temperature of the atmosphere.

After complete settling the acid will form an under layer, the oil floating above. This separation of the product, it will be noticed, is quite the reverse of what takes place in the hard-wood works, where the heavy viscous tar falls to the bottom.

The Pine Oil.—This may be considered as embracing all the oily products from the wood, and separates from the pyroligneous acid as a deep red to black oil, according as it is viewed in small or large quantities. Its specific gravity ranges from 0.970 to 1.030.

Even after long settling it retains considerable acetic acid, requiring 2 per cent. of its weight of ordinary bicarbonate of soda to neutralize it. The flashing point varies above and below 120° F., according to the manufacture, thus rendering the crude oil dangerous if heated by direct fire in an open vessel.

The main application of the crude oil is for creosoting purposes, but when so applied it should be free from the light oil of the distillation, and also subjected to a treatment to remove other volatile products, together with methylic alcohol, acetic acid, and water.

The presence of the volatile constituents renders the crude oil very inflammable, and immediately after forcing into the wood evaporation ensues, thus decreasing the weight of oil per cubic foot in the treated timber, and tending to open the interstices of the wood.

Pieces of yellow pine sap wood treated with the crude oil (by simple immersion), and subjected to a temperature varying from 32° to 100° F., continued to lose weight for 19 months, showing thus the necessity of removing these light oils. This removal is best effected by subjecting the crude oil to a short fractional distillation, the removal of 15 to 20 per cent. of the oil leaving the residue in excellent condition for the creosoting process. This operation not only removes the dangerous and non-permanent constituents of the crude oil, but increases the percentage of the phenoloid bodies and the heavy hydrocarbons to which the creosoting process owes its merits.

Another purpose to which the pine oil has been applied, is the manufacture of paints.

It makes a good black paint for iron, but is unsuited for light colors, which it darkens.

Upon wood it works badly, on account of its tendency to pass from the pigment into the wooden surface painted.

The medicinal properties of pine oil are attracting considerable attention, and are due probably to its contents of creosote.

The Pyroligneous Acid, when well separated from the pine oil, has a yellow to yellow-red color, and contains 4 per cent. of hydrated acetic acid.

In its crude condition it is suitable for the manufacture of pyrolignite of iron—the black dye. It is also an excellent disinfectant, and as such is used in the southern cities.

It may be worked up for finished products, like the hard-wood acid.

Besides the manufacture of wood alcohol, acetate of lime, pyrolignite of iron, charcoal, and creosote oil, there is a wider field for the manufacture of other and more valuable products from the pine, and the present aspect of this industry leads to the belief that the sound of the axe will soon become more frequent in the southern forests.

THE KNICKERBOCKER AVENUE SEWER OUTLET.

BY E. SCHÖNEY.

THE Knickerbocker Avenue Sewer Outlet, recently completed in Brooklyn, will stop forever one of the sources of pollution which have made Newtown creek a byword. The State Board of Health, aided by a proclamation issued by Governor Cornell, began in 1883 to wage an energetic war on the manufacturers who emptied their waste products into this interesting stream, whose banks were lined with many thousand tons of reeking stable manure, while fat-boiling and bone-boiling establishments, fertilizer works, distillery works, and thirteen petroleum refineries, besides some thirty other offensive trades, contributed to the nuisance. In addition to these were the Knickerbocker Avenue Main Sewer, furnishing an outlet for twenty-two miles of sewers, and continuously discharging a mass of sewage into the creek, which increased the mortality, while it depreciated the property in the neighborhood.

The new sewer extension carries all the sewage from this source to the East river, besides contributing greatly to the relief of the low or "flooded district" of Williamsburgh. The property owners in the region are feeling its benefits, for it not only relieves Newtown creek, but furnishes an incentive to building in the back districts of Williamsburgh.

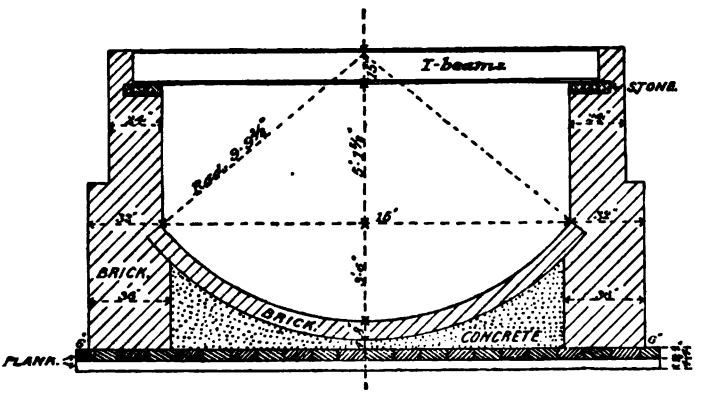
This great sewer can discharge at its maximum two hundred thousand gallons per minute. Its total length is about eleven thousand (11,000) feet, and the velocity due to the fall is such that a boat would drift in it from Newtown creek to the East river in forty-six minutes. The area of the sewer determined by calculation, was made equal to a circle of 12 feet diameter.* For a length of over 10,000 feet the interior section is that of a true twelve-foot circle, where the height of the street above the water line admits of it; where the depth was insufficient, sections were designed to meet the necessities of the situation, but having the

* Formula used was as follows:

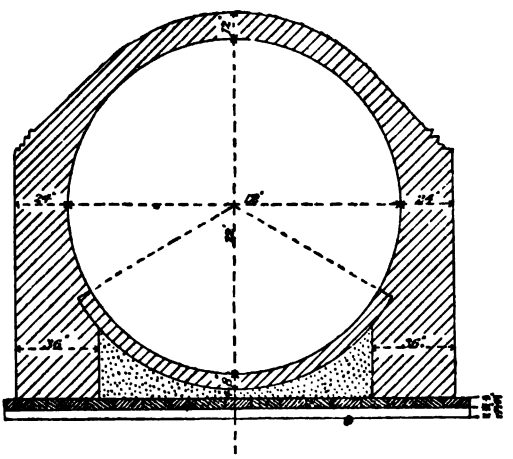
$$\frac{3 \log. A + \log. N + 8}{10} = D.$$

A = area drained; N = distance to fall one foot = 2795. The constant 8 was used to allow for heavy rainfalls, friction, etc.

KNICKERBOCKER AVE.
SEWER EXTENSION.



MEAN OUTFALL SECTION.



GENERAL SECTION. I & II.

PLATE 3.

same area. For about 1000 feet the area is reduced to that of a ten-foot circle. The accompanying plate shows the section of the sewer. The work was divided into two sections, each of which offers some interesting features of construction. It was prosecuted under the direction of Assistant Engineer L. R, Clapp, of the Brooklyn Department of City Works.

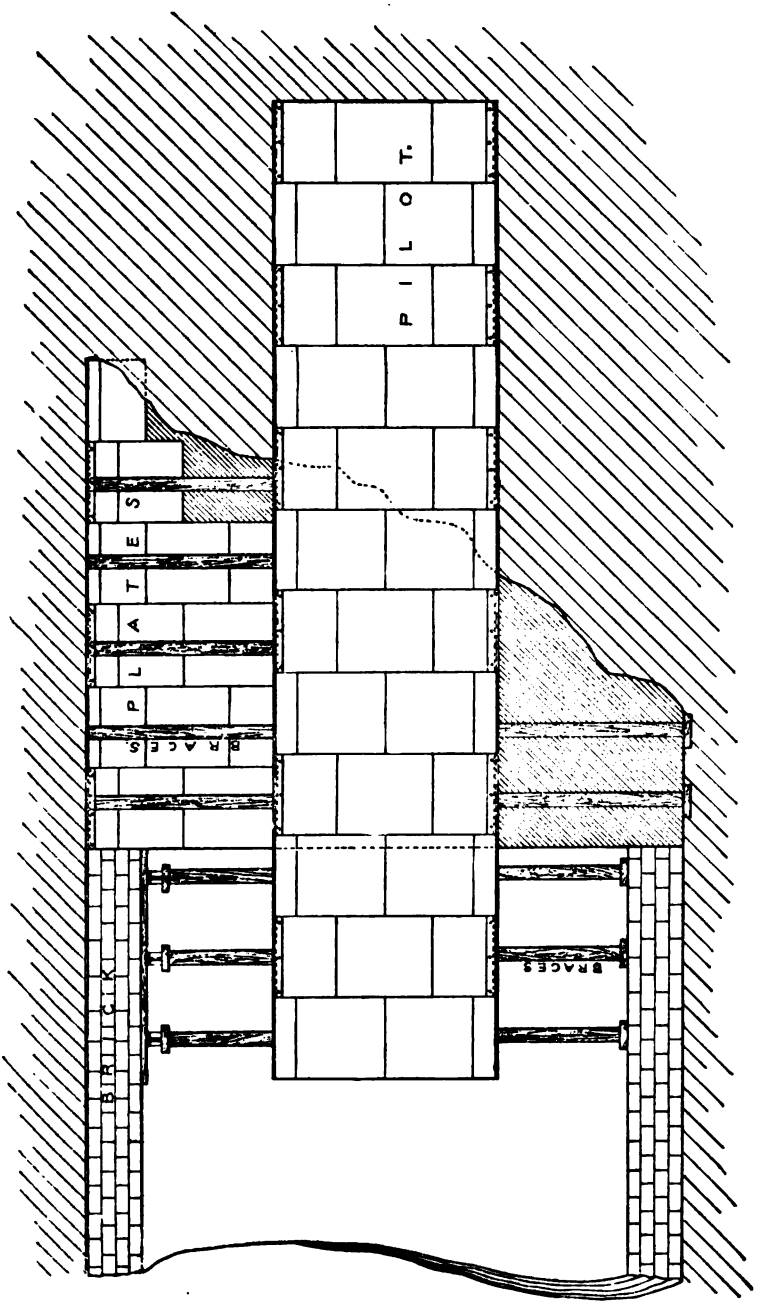
Section I.

Four thousand feet of this section were built in tunnel, to accommodate property owners and residents of the street through which the sewer runs, who would have suffered continual annoyance had the ordinary method of construction by "open cut" or trench been employed. To ascertain the nature of the material to be encountered borings were made in each block. The boring implement was an iron pipe 2¼ inches in diameter, into which a smaller pipe carrying a jet of water and a bit was introduced; this facilitated the penetration of the large driven pipe and brought the material passed through to the surface. The results of these borings were not reliable.

Tunnel Construction.

The method of tunnel construction adopted was similar to that used in building the Hudson River tunnel, the chief feature being the application of the pilot tunnel first devised and employed by Mr. Anderson. The illustration shows the position of the pilot with reference to the tunnel proper. In construction it was a cylinder 5 feet 6 inches in diameter, made up of plates, six to one complete ring, and 1 or 2 feet wide, the half-plates being used in very bad material. The plates were made of ¼-inch boiler-iron, and were joined together by inside flanges formed of $3 \times 3 \times \frac{3}{8}$ inch angles riveted to the plates and bolted together. Fastened to one end of each segment was a plate $4 \times \frac{3}{8}$ inch, which projected 1 inch outside the surface of the completed cylinder. These projections formed continuous lines from end to end of the pilot, and served as supports for the timbering.

The pilot-tunnel was pushed 10 or 15 feet ahead of the main excavation, and was consequently well supported at the forward end. Two men, working with barrel-staves, shovels, or hand-drills, scooped out the material sufficiently to put the forward plates in place successively, beginning at the crown; the excavated mate-



LONGITUDINAL SECTION SHOWING METHOD OF CONSTRUCTION.

SECTION SHOWING METHOD OF BRACING.

SECTION SHOWING ARCH CONSTRUCTION.

rial, mainly sand, was thrown into the finished tunnel at the rear of the pilot, and carried to the shaft elevators in cars. The back of the pilot was supported on a double set of 4 × 4-inch struts, abutting against the completed brick-work, over which the pilot always projected 3 or 4 feet. The excavated earth back of the pilot, as well as the earth under it, served to maintain its form and alignment.

The brick-work was built in sections 10 feet long. Before removing the material for the full tunnel section, a support was necessary for the roof and sides, made of parts easily handled, and strong enough to prevent all settlement or escape of the soil, a very important precaution where much running sand is encountered. In this case the roof was made of plates with inside bolted flanges. The plates used in earth or hardpan were 3 feet long by 2 feet wide, and those used in sand were 3 feet by 12 inches. They were made of No. 12 iron, with 2 × 2 × ¼-inch angles riveted to them. Average weight of large plates (3 × 2) was 52½ pounds; of the small plates (3 × 1), was 36 pounds. Each large plate had 18 bolt holes; each small plate, 16. Taking the general run there were 8.25 bolts to 1 large plate, 7.6 bolts to 1 small plate. The plates broke joint, so that there were six in one ring and five in the next. The crown-plate was first put up and supported by a 4 × 4-inch brace, resting on the top of the pilot; the side plates were next put in place, bolted to the adjoining plates, and propped as shown in the section. Planks were sometimes used to distribute any unusual pressure against a plate. The roof-plates in place, the sides and bottom of the circular excavation were held by planks 9 × 1¼ inch and 10 feet long. Each plank was temporarily secured by 2 × 2-inch struts (abutting against the pilot). Three planks were set thus, when a short length of 2 × 10-inch plank was set and secured by a 4 × 4-inch strut, to give greater security, as with the iron plates. In removing the material from under the pilot, connection was first made between the two sides near the forward end of the pilot, and the excavation was then carried towards the rear end; for it was necessary to leave the rear support as long as possible, the pilot, with its front end well supported, acting as a beam to hold the weight above. Thus the invert was entirely clean and free from any obstructing timbers for the working length of 10 feet. The light struts were removed as the brick was laid, and

any tendency to deformation was checked by replacing the struts on top of the brick.

The tunnel itself can be braced inside to resist any extraordinary pressure. As soon as the excavation was completed over a 10-foot section ahead of the finished tunnel, the brickwork was commenced in that section. The invert was laid as usual, profiles being carefully set to grade determined by engineer's test on the last completed section. For turning the upper arch, centres made of wrought-iron T ribs were used. These ribs had shoes riveted to them, and they rested on a short timber supported by the centre projecting rib of the pilot at one end and in put-lock holes left in the brick masonry at the other; ordinary lagging was then placed on these ribs. From the "Section showing arch construction" it will be seen that the iron plates in the roof and the plank at the sides and bottom—if the bottom is bad—are bricked in. For plates bricked in, the contractors were allowed $22,110; for bolts, $3021. The brickwork was let out by contract to gangs, each gang consisting of four masons; there were four bricklayers to each heading, and since the men were paid by the foot of complete section, rapid work was accomplished. Notwithstanding the treacherous and unstable character of much of the material encountered, the work was pushed ahead rapidly day and night. In the month of March, 1886, 690 feet of tunnel, an average of more than twenty-five feet per twenty-four hours, were constructed through sand and occasional quicksand. Three shafts were used, and headings were driven simultaneously east and west. This system of tunnelling gives an exact idea of the nature of the material ahead of the main work; it serves to hold firmly the sides of the excavation, preventing caving in, the spaces left outside of the plates are few and are readily filled; and, further, it involves the minimum amount of waste in the case of circular tunnels.

For 4000 feet of tunnel and 1000 feet of open-cut work ("general section I. and II."), the contractors received $296,910. Profit on the work (including replacing old sewer in the centre of the street by pipe sewers under the sidewalks) was about $25,000. The method of dumping the sand-car may be of interest. The faces of the forward wheels of this car are narrower than those of the rear ones, thereby permitting them to pass between the ends of the rails, which are inclined upward at a sharp angle, and rest

in the curved parts of inner rails. The rear wheels mount the inclined rails, thus tilting the car and dumping the load.

SECTION II.

The upper section of this work, through streets generally too low to admit of tunnelling, was constructed by the "open-cut" method, and affords some examples of rapid construction. In August, 1885, 850 feet of the work (more than thirty-one feet per twenty-four hours) were completed. This section required the opening of a trench at least seventeen feet wide in a street with a thirty-foot roadway. A resort to the older methods of construction would have filled the sidewalks with excavated material, thus practically closing the street to business for months. This was avoided by employing the ingenious excavating machinery devised by Mr. H. A. Carson, which, by the use of buckets attached to rolling pulleys, transports the material to a distance.

By the use of this method no excavated material is left upon the sides of the street, the back filling over the completed work is done quickly, and it is deposited uniformly over the newly laid masonry.

The total cost of Section II, the length of which is 6380 feet, was $235,784. Of this, $165,132 was paid for 5400 feet of 144″ sewer, and $17,520 was paid for 927 feet of 120″ sewer. For sheeting plank, braces and rangers, 1,109,240 feet were used, which at $20, cost $22,184. 473,350 feet of foundation, or "bottom plank" (4″ × 12″) was used; this, at $25, cost $11,833.

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NOTES AND ABSTRACTS.

The Use of Bore Holes for Rope, Steam and Water Ways in the Anthracite Region.

Shenandoah City slope, situated in the southeastern portion of Shenandoah, Pa., was down three "lifts," or in other words was down to the third level, below water level. At this point the basin or synclinal axis, dipping east, was reached. In 1883 this third or lower level was pretty well worked out, as far as *new* work in the Mammoth seam was concerned, and it was deemed advisable to develop new workings by means of an inside slope which should reach the basin at its lowest point. This lowest point was found to be about 6700 feet, measured along the gangway, east of the foot of the slope, consequently line was given and a slope started at this point. Owing to the fact that the Mammoth seam does not come to the surface on the company's property in this particular locality, it was impossible to locate the engines and boilers at any place but inside the mine, unless bore holes or a rock slope were resorted to. Bore holes being by far the cheaper and just as convenient, were decided on; the engines and boilers are on the surface, the inside workings are free of the gas and steam which would be naturally thrown off if they were inside, and the whole plant is run far more economically and with better results than if it was located in the mine.

Points were marked on the surface, on line with the centre line of the new slope, and at a certain distance above the gangway in the old slope, lower level, at which point the bore holes were to be started. The surveys were made, beginning at the point inside, which was marked for the bottom of the hole, and continued out the gangway (by the way a very crooked one), up the slope and over the surface to a point near where the bore hole was to be located. This work was then traversed, and the course and distance necessary to strike the required spot were calculated.

The machinery used in drilling the hole was similar to that used in the oil regions of this State for sinking oil wells, and worked on the jumper principle.

An 8-inch hole was then bored, 244 feet to the old breast in the bottom member of the Mammoth seam, above the old gangway or landing of new slope.

This hole was then lined with a 5⅝-inch casing through which the rope travels, and the space between the casing, and the rock and drive pipe, filled in with Rosendale cement. Another hole six inches in diameter was drilled to the same workings and from the surface to the top member of the Mammoth seam, a distance of 118 feet. Two lines of two-inch gas pipe, and from the surface to the bottom member, two similar lines of pipe were inserted. The interstices were then filled with Rosendale cement. The two pipe lines to the bottom member are used for speaking tube and bell wire to engineer at the machinery on the surface. The rope used in hoisting is a 1-inch Hazzard wire rope.

A drill hole for the same purpose 78 feet deep, 8-inch diameter, lined with 4-inch casing, is now in use at the Philadelphia and Reading Coal and Iron Company's Schuylkill Colliery, near Mahanoy City, Pa. At East Franklin Colliery, in the western part of the Southern anthracite coal field, there are two bore holes, each 8-inch diameter, cased and

cemented, 763 feet deep. These holes are 7 feet apart and are used to hoist from a double track underground slope.

At Nanticoke, Luzerne County, Pa., the Susquehanna Coal Co. has a bore hole in successful operation as a rope way. These holes have also been successfully used as steam-pipe ways and for water ways in the following instances, which, as in the rope ways, is only an incomplete record of the many instances in which the bore holes have proven valuable.

At Lincoln Colliery, in the western part of the southern anthracite field, an 8-inch hole 140 feet deep, is used to convey steam to a pump inside, through 4½-inch steam pipe. As this hole was remarkably dry, it was not cased.

At the Meadow Brook Colliery, in the Lackawanna Valley, a 12-inch hole, cased with 8-inch pipe and cemented, is used for column pipe from pump inside, and an 8-inch hole with 5⅝-inch casing, cemented, is used for passage way for a 5-inch steam pipe line to the pump and a pair of hoisting engines inside. This last hole was a very wet one, and the casing had to be inserted to protect the steam pipe and also to prevent loss of power by condensation.

At the Clear Spring Coal Company's Colliery, West Pittston, Pa., a 6-inch hole was driven 270 feet and a line of steam pipe 4½ inches in diameter inserted. This hole was not cased, and though only about ¼-inch stream of water flowed down the hole, the condensation of steam was so great that a pressure of 120 pounds per square inch on the surface, only realized 40 pounds pressure at the bottom of the hole. Afterwards the space between the rock and the steam pipe was cemented, a 3-inch steam pipe placed inside of the 4½-inch pipe, and the steam pressure at the bottom of the hole was the same as on the surface. These holes have also been successfully used in fighting mine fires, for providing water supplies, and for other purposes connected with coal mining, which will be fully treated on in future numbers of our paper.—*Condensed from Colliery Engineer*, October, 1887.

Distillation of Wood in the North.

The subjoined extract concerning hard-wood distillation, will be of interest in connection with the article in this number upon the similar use of pine in the South.

The Cadosia Chemical Company, Cadosia, Delaware County, N. Y., has several establishments in that vicinity for the distillation of wood, which has now become an extensive and an important industry.

Almost any of the harder varieties of wood will answer, but those chiefly found and used by this company, in the region it now occupies, are birch, beech, and maple. Pine, hemlock, and soft woods will not answer. The general operations and products of the company are as follows:

Contracts are made with the neighboring farmers for the purchase of standing wood, on which an agreed amount is paid in advance, balance payable as fast as the wood is cut by the company. The wood is delivered at the works in ordinary four-foot lengths, and is then piled in the distilling retorts, of which there are in the Cadosia still-house twenty-four pairs. The first products of the distillation, consisting of alcoholic

vapors, are passed through a condensing worm, and the liquid thus produced is subsequently redistilled, and this product then sold. Most of it goes to Binghamton, where it is refined and put on the market as wood alcohol. The second products of the distillation, consisting of acetic vapors, are condensed as before described, and the liquid is mixed with lime, thorough mixture being effected by mechanical means, thus producing acetate of lime—used in cloth-printing works. The crude acetate is placed above the retorts or racks, where it is dried, and is then ready for market.

The third products of the distillation, consisting of tarry matters and naphthas, are shipped as produced, and subsequently refined.

The last products, consisting of heavy tars, are used at the works as fuel. When the distillation is finished, there remains within the retorts a mass of clean and beautiful charcoal, ready for market, and all of it is sold to the steel makers. Most of it goes to Troy, where it is chiefly used in the production of fine steel.

The principal fuel used in these works is bituminous coal, which, together with the crude lime required, is brought to the works by railway. —*Oneonta Herald.*

Tunnelling.

A letter received from Mr. L. C. Easton, Engineer on the new Croton Aqueduct for New York City, calls attention to some details of the close instrument work done in the alignment of the tunnel headings running south and north respectively from shafts Nos. 2 and 3. As the accuracy in meeting of the two headings has been generally noticed in the weekly technical journals, we will content ourselves with certain details only from his interesting correspondence:

"The shafts are 6200 feet apart; are 17½ by 8 feet in section, and 370 feet deep from track grade of dump down to invert grade, and are very wet.

"Line in the tunnel was obtained by suspending two very fine steel wires in the shaft with 24-pound flanged plumb-bobs attached at the bottom, the bobs being immersed in water with a thin layer of heavy oil on the surface of the water.

"These wires were set on line at the surface, and then the transit was ranged into line with them at the bottom, and points set in the roof of the tunnel about 300 feet each way from the shaft, for a permanent base. From the size of the shaft it was only practicable to get a 16-foot base for the wires, in which an error of one-thousandth of a foot at one of the wires would make a difference of about two-tenths of a foot at the point of meeting, 3100 feet away."

The alignment was so accurately made that two drill-holes lined in when the headings were 10½ feet apart struck each other squarely. **

We call the attention of our readers to the following circular:

At the last session of the National Academy in New York City, November 10, 1887, an informal conference was held by the undersigned in reference to the establishment of seismoscopes with suitable time-taking attachments at the Astronomical Observatories of the country. It was generally recognized that, for many reasons, and especially on account of convenience in obtaining standard time, astronomical

observatories offered exceptional facilities for continuous observations in Seismology, and it was agreed to establish seismic stations at the observatories and laboratories under the direction of the undersigned, and to urge similar action on the part of others favorably situated.

In many physical laboratories accurate time-signals are received every day, and it was believed that those in charge would willingly undertake the small expense of equipment and the trifling labor of maintenance, in order to co-operate in the inauguration of this important study.

It was therefore resolved to issue this circular of information to those likely to be interested, in order to invite co-operation, and to ascertain how many were prepared to join in the work.

It was agreed that the seismoscope to be used should be substantially of the pattern exhibited by Professor Mendenhall, and described by him in a paper presented to the Academy on the first day of the session. The cost of one of these instruments will not exceed five dollars if twenty or twenty-five are manufactured at one time. Each station should be provided with *two* seismoscopes, mounted in buildings separated from each other, in order to eliminate false records arising from local disturbances.

Where the observer is already provided with good clocks, one of which may be stopped occasionally (either by an actual earthquake or in a test of the apparatus), without materially interfering with his time-system, or, where he wishes to provide his own arrangements for securing the time record, it will only be necessary to procure two seismoscopes at a cost of ten dollars.

A complete equipment will include a clock, with electro-magnet for stopping, and seismoscope with one or two cells of battery suitable for open circuit work. Experiments which have been going on for a year or two with a "Seth Thomas Regulator, No. 2," seem to prove that it is a time-piece of sufficient accuracy for the purpose, and the clock, seismoscope, and stopping apparatus can be furnished for about twenty dollars. It would be well to duplicate the equipment; but, as already stated, two seismoscopes are considered essential. By proper arrangements they may be made to operate upon the same clock, so that one clock with stopping apparatus would be sufficient. After the apparatus is properly mounted, the only labor connected with its maintenance will consist of daily observations of the error of the clock, and records of monthly tests of the entire system. Earthquakes, especially such as can be detected by the use of a seismoscope, are much more frequent than is ordinarily supposed, and it is believed that a number of seismic stations, well distributed over the country, cannot fail to yield interesting and valuable results, even within a year or two after their establishment.

If you are willing to join us in this work, and desire to procure the necessary instruments, or if you wish any further information concerning the details of the plan, please address T. C. Mendenhall, Rose Polytechnic Institute, Terre Haute, Ind.

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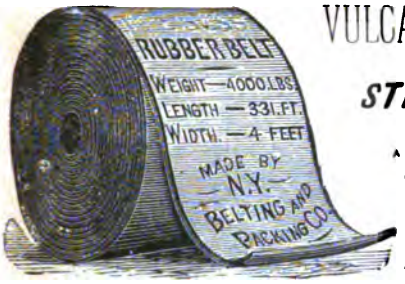

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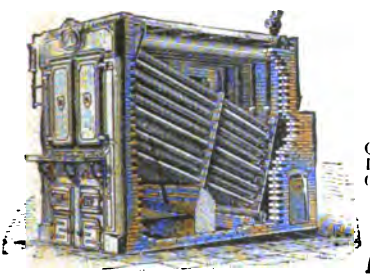

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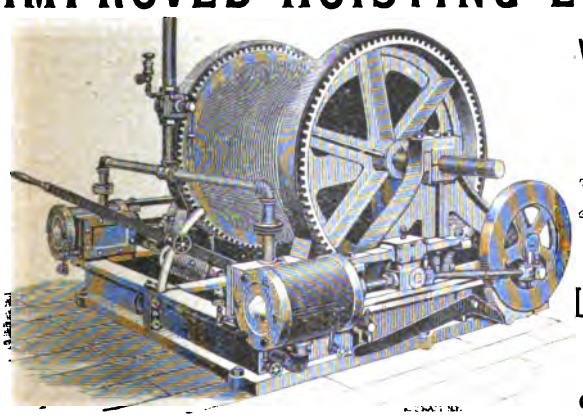

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SYSTEMS OF WEIGHT AND MEASURE.*

BY PREST. F. A. P. BARNARD, LL.D., D.C.L.

IF we could penetrate the mists which enshroud and obscure the beginnings of human society we should find nothing to interest us more than the gradual growth among men of systems for the measurement of quantity. I use the word *growth* advisedly; for though we cannot trace these institutions back to their inception, we can trace them far enough to be assured that they had their origin in general usage insensibly established, and were not created by deliberate premeditation or imposed upon society by superior authority. Indeed, it was only at a very late period in the history of civilization that the idea of founding a metrological system upon an invariable standard of quantity or constructing it in its methods according to scientific principles, occurred to any statesman. Though laws regulating systems of weight and measure have been enacted in almost every age and every country, yet these laws have almost universally been designed to confirm and perpetuate usages already in existence. It was not until near the close of the 18th century that a definite effort was made to establish a system for the measurement of quantity of every description upon truly scientific principles, adapted and intended for the use of all man-

* Lecture delivered at Columbia College, January 28th, 1888.

kind. This effort was made in the constituent assembly of France in the year 1790, when it was proposed by the famous Talleyrand, then Bishop of Autun, and a member of that body. It is the system known as the Metric System, definitely adopted in France in 1799, and now legally established over a large part of the civilized world, that is to say, in countries embracing nearly five hundred millions of people.

My design this morning, is to speak of the general principles on which systems of metrology are founded, and to give some account of the history of their growth. The subject, I am aware, is not particularly attractive. It affords no opportunity for picturesque word-painting to gratify the fancy, nor for brilliant visible illustration to dazzle the eye. It recommends itself, nevertheless, by the intimate relation in which it stands to the substantial interests of civilized society. Some mode of determining with exactness, quantity, dimension, weight, capacity, is necessary to every transaction of business which takes place between man and man. Nor is its importance confined, as may at first thought appear, to mere exchanges of merchandise; that is to say, to the operations of commerce, though to these its necessity is vital; but it extends through all the applications of industry to the supply of human wants or the provision of human comforts, even the simplest. Some definitely settled system of weights and measures is absolutely indispensable to the intelligent direction of labor, in order to the promotion of industrial progress and the growth of the wealth of nations.

For wealth is the product only of labor. Even the great gifts which nature bestows, the corn and the wine and the oil which she yields so profusely to strengthen the frame or to gladden the heart of man, she yields only as the reward of patient toil; while the gold and the gems of which the value seems to inhere in themselves, or to be what is called intrinsic, are unavailable for human uses till they have passed the refiner's furnace or the lapidary's wheel.

The artificial conditions of society allow wealth frequently to accumulate in hands which contribute nothing directly to its production; the necessities of society require, indeed, that many should be occupied with distribution rather than with the production of wealth; and that many others should be engaged in those avocations which are necessary to maintain order, to promote the

diffusion of intelligence, and to guarantee to industry the secure enjoyment of what it produces. These all contribute indirectly to increase the value of the objects which industry creates; but the substance created, the visible material to which this value attaches, comes at last from the strong arm of labor, without which there could be no wealth to be protected or enjoyed.

The rudest form of labor is the direct application of muscular force to accomplish a useful end. Such labor may be put forth by brutes as well as by man; but brute force contributes directly to the production of wealth only in a very moderate degree. It is the precision with which force is directed to definite ends which is chiefly instrumental in giving value to products. The glory and the power of modern industry is due to the skill which guides the hand of the artisan, and to the variety and the perfection of the implements which enable him to apply this skill.

But precision in the arts of industry exacts, as an indispensable condition, the possession and use of instruments by means of which the minutest differences between material things, whether as to figure, or dimensions, or weight, or volume, may be determined with the severest accuracy. And hence, while the most frequent use which we see made of measures and weights in the business of everyday life consists in their employment to determine the quantities of commodities which pass from hand to hand, yet, in point of fact, it is strictly true that, without them the commodities in the possession of mankind worth preserving or exchanging would be too insignificant in amount to form the material of a regular commerce.

Systems of weight and measure are thus seen to be essential to construction and production, as well as to exchange. And in the rudest stages of social existence some such system is sure to grow up, though it may, and almost inevitably will be, in its origin, exceedingly imperfect. Even the isolated savage will be led by the exigencies of his own difficult life in the forest to adopt some expedient by which to compare magnitudes—say lengths, or bulks, or heights, or distances. In regard to distances, especially, his need of some criterion of judgment will be very early felt. His life is one of constant movement, and there are numerous haunts to which he must frequently resort. There are the hunting grounds over which he pursues his game, there are the more secluded spots where he lays his traps or constructs his pitfalls, there is the landing

on the forest stream where his rude canoe is hidden, there are the favorite pools where he finds his fishing most successful, there is the spring to which he habitually resorts to slake his thirst, and there is, finally, the rude construction of poles and bark and skins beneath which he finds shelter from the inclemency of the weather, or passes in sleep the silent hours of darkness. A notion of the relative situation of the points which he is thus obliged frequently to revisit is, of course, to some extent acquired, by noticing the unequal intervals of time occupied in passing from one to another; but in the absence of any timekeeper, such a notion can be only the vague one of greater or less. A more definite system of measurement seems to have been everywhere suggested by nature herself, applicable, it is true, only to the extent to which the power of the savage mind over numbers is capable of reaching, which is to count the steps taken in passing from point to point. Thus, the *pace* is for all mankind the earliest elementary itinerary measure; and even in a state of civilization it continues to be universally used among men on account of its great convenience for rough determinations. When, with advancing cultivation, a larger unit of measure was found desirable for larger distances, this larger unit was made a multiple of the original elementary measure, the pace, as witness the Roman *mille passum*, or thousand paces, from which was formed the word *mile* which has come down to our time.

The pace was probably long in use as a measure before the idea occurred to substitute for the actual step an artificial rule, or rod, or thong as long as a step. In the work of construction, moreover, as in the preparation of shelters, or of boats, or of implements of war or of the chase, other expedients would be needed for determining dimensions; and these would most probably be found in the dimensions of members of the person himself employing them; as the length of the forearm, the extent of his span, the breadth of his palm, or the length of his foot.

The mode of measuring thus introduced would probably consist, in practice, in the immediate application to the thing to be measured of the member adopted as a unit. The construction of a measuring *rule* would imply the conception of the idea of measure in the abstract; an idea not likely to arise until brought forcibly out by the discordant results observed in the measurements of different individuals. But when at length measuring rules were introduced,

as they must have been early in the history of organized society, for the purpose of securing uniformity, these artificial measures continued as a matter of course to be called by the name of that member of the body from which they were derived. The length given them may have been the average length in many individuals, or it may have been the actual length in some one individual, eminent in place or celebrated for his achievements. The foot-measure originated in Greece in a period where history and fable are so intimately mingled that the manner of its origin is lost; but tradition ascribes the earliest Greek foot-measures to Hercules, who is said to have laid out the stadium or foot race course of the Olympic games so as to be six hundred times the length of his own foot. The Hon. Mr. Sumner, in a speech before the Senate of the United States, delivered in 1866, in favor of the Metric System of weights and measures, gives a different version of this tradition, the authority for which I do not know. He says that the stadium was the distance which Hercules could run without taking breath, and that this divided by 600 gave the Grecian foot. He should have said not the Grecian foot, but the Grecian-Olympic foot; since Greece had quite a number of foot-measures besides, quite different from this.

At a much later date, but still nearly 800 years ago, the British yard was regulated from the length of the arm of Henry I. According to Professor Wachersbarth, of the University of Sweden, at Upsala, it is historically ascertained that this measure had been previously about 39.6 inches long, exceeding slightly the more modern metre. That it was so considerably reduced is now seen to have been a serious misfortune.

The earliest measure of length of which we have any record is the cubit. This was an antediluvian measure, and was used by Noah in the construction of the ark. It was likewise used by the children of Israel, and it was employed by the Egyptians in the very earliest of their massive architectural constructions, that is to say, the great pyramids of Gizeh. By a curious accident, one of the identical original rules employed by Egyptian builders has been preserved down to our own time, and is now in the British Museum. It had been accidentally left in a hollow portion of the masonry of a temple at Karnac, and built up out of sight. Modern inquisitiveness, burrowing among the ruins of three thousand years of decay, at length discovered it in its hiding-place, and

brought it forth to light, perfect as when it was left there by the forgetful stone-mason almost in the morning of time. It is a rule two cubits in length, and it measures exactly the breadth of the entrance passage descending into the great pyramid of Cheops. Five times this rule measures, moreover, the breadth of the so-called King's chamber in the same pyramid, and ten times the same rule measures the length. Yet the pyramid is some centuries older than the temple in which the rule was found, so that the accordance furnishes a striking proof of the permanence of measures among that ancient people; a degree of permanence of which we have few modern examples.

The cubit was originally derived from the length of the fore-arm, measured from the elbow to the extremity of the middle finger. This, in a man of ordinary stature, is about nineteen inches; but the cubit measures which have been actually used among different peoples have differed from each other very materially, varying from 17 inches to more than 25. It is manifest that all these various cubits cannot have been taken from the arms of human beings. Their variety sufficiently indicates that many of them were arbitrarily established; but the common name by which they were all known is a standing proof of the fact that the original cubit *was* so taken; since the word cubit (*cubitus*, Lat.) is the name of the elbow, the point from which the measurement begins.

The modern ell, till recently extensively in use on the continent of Europe, and not yet wholly superseded, had apparently a similar origin, the name being derived from *ulna*, another word for elbow. Ulna was the Roman name for a measure, and this form of the word is still nearly preserved in the *uln* of Denmark and Sweden. But the ell has undergone with time, much more extraordinary variations than even the cubit. Nearly one hundred ell measures of different lengths may be reckoned up in Europe, of which the shortest, that of Presburg and Mannheim, is hardly twenty-two inches long, and the longest, that of Rhenish Bavaria, is more than forty-eight. The varieties of foot-measures have been more numerous still, and their values still more largely discordant, varying from about nine inches to upward of twenty-four. Yet the original foot was, no doubt, derived from the member of which it takes the name; and this derivation took place beyond question, independently in many different countries, and among many different

peoples. Conclusive evidence of this fact is found in the uniformity with which the name given to this measure by different nations is identical with that given in their several vernacular tongues to the human foot. If the measure had been borrowed, it is probable that the name would have been borrowed along with it. But the Greek said *pous*, the Roman *pes*, the German *fuss*, the Spaniard *pie*, the Portuguese *pe*, the Dane *fod*, the Swede *fot*, and the Englishman *foot*. How singularly unfortunate it seems to be that when all northern and western and southern Europe had in name, from one end of the continent to the other the very same measure of length, derived from the very same origin, there were hardly two towns thirty miles distant from each other throughout this whole continent, in which this same measure meant the same thing.

Besides the cubit, the ell and the foot, nearly all the other measures of length in use among modern nations seem to have been derived from some dimension of the human person. Such are the *yard*, which Mr. Adams derives from the Saxon *Gyrdan*, to gird, as signifying that it is the measure of the circumference of the body, the *palm* which is the breadth of the hand, and the *hand* measure itself; the Italian *braccio*, which is the length of the arm, the French *pouce*, the breadth of the thumb, the English *span*, which is the extreme spread of the fingers and thumb, the fathom, from the Saxon *fadhm*, embrace, the length of two arms, etc. Apparent exception to this principle of derivation are the inch, which comes from *uncia*, signifying the twelfth part, and the line, which has no especial significance. These are of comparatively recent origin, introduced after civilization had attained some advancement. When the measures exceeded the largest dimension of the human person, their names were otherwise derived. The French *toise* is an example, from the Latin *teda*, *tendere*, *tensum*, signifying stretching. The first toise was, therefore, evidently a flexible measure. Rod, perch (pertica), explain themselves.

Two inferences may be drawn from this view of the origin of measures of length. The first is, that it is folly to attach any special importance to the actual values of these measures now in use, on the ground that they are in any sense natural measures, or correct copies of their nominal prototypes. The length of our foot-measure is, in point of fact, about two inches in excess of the length of the average foot of man. The length of the human foot is given by Dr. Thomas Young, in the *Encyclopædia Britannica*, at

about 9¾ inches. In Dr. B. A. Gould's report on the "Military and Anthropological Statistics of American soldiers," published in 1869 by the U. S. Sanitary Commission, are given measurements of the feet of 16,000 adult men of all nationalities, with a mean result of $10\frac{1}{20}$ inches. The different nationalities varied between $9\frac{9}{10}$ and 10¼ inches.

The second inference is, that these standards of measurement, having been originally the offspring of accident, and having since suffered frequent change through carelessness or caprice, are not likely, any of them, through any *a priori* probability, to possess a peculiar fitness to serve as the basis of a system of weights and measures, constructed on scientific principles.

Similar remarks may be made in regard to the earliest measures of capacity and of weight. All early measures of capacity must have been purely arbitrary; derived, perhaps, from the contents of some such natural vessel as a gourd, or the shell of a cocoa-nut. It is known that even an egg-shell served the same purpose. Civilized people, however, have generally derived such measures from their measures of length.

The use of weights implies an acquaintance with the balance, and, therefore, some degree of advancement in civilization. The original units of weight, like the capacity measures, were altogether arbitrary; but inasmuch as the earliest weighings were used to determine quantities of grain and of common wines, the unit was made to correspond to the amount of these substances which would fill a vessel of moderate size. And thus, as it became very soon apparent that a given bulk of corn was lighter than the same bulk of wine, there arose the duplicate systems of weight, which we call avoirdupois and Troy. And because equal weights of these two substances correspond to different bulks, there in like manner arose the duplicate systems of measures of capacity, which we call liquid and dry measure.

This duplication of systems, which by unnecessarily complicating the subject seems from our standpoint to be an evil of serious magnitude, was, nevertheless, only fifty years ago, alleged by Mr. John Quincy Adams, then Secretary of State of the United States, in a very elaborate and learned report on weights and measures made to the Federal House of Representatives, to be a most admirable provision, furnishing what he called a uniformity of proportion between weights and the measures of capacity, in contradistinction

to the uniformity of identity, which would exist if all substances were weighed by the same weights and measured by the same measures. The report here referred to prevented probably a reform of our metrology at that time—a time when it would have been comparatively easy; and to this day we continue to use the wet and dry measure, and the avoirdupois and the Troy weight. But Great Britain, from whom we derived these equivocal blessings, was engaged at the very time when Mr. Adams was writing his report, in a study of the question how far it might be possible to reform the irregularities of her system; and though in the end she halted half-way in the good work, yet she went so far as to discard entirely from her measures of capacity the feature of uniformity of proportion, so much commended by Mr. Adams. She abolished at one stroke of the pen all her preëxisting measures of capacity, both wet and dry, and established the imperial measures which she now uses. Since 1824, therefore, the British gallon has had a capacity about one-sixth greater than the American, and the British bushel a capacity about a thirtieth greater.

The earliest statutory definition of a standard measure of capacity in England now on record, which was at the same time a statutory definition of the standard of weight, is contained in an Act of the reign of Henry III., passed in the year 1266. This Act declares that an English penny, then called a sterling, round, new, and without any clipping, shall weigh 32 wheat corns from the middle of the ear, and that the weight of 20 pence shall make an ounce, 12 ounces 1 pound, 8 pounds 1 gallon of wine, and 8 gallons of wine 1 London bushel. In these wheat corns we have the origin of our word grains as applied to weight. But this grain was not the modern grain in value, nor this pennyweight the modern pennyweight, nor this pound the modern pound, either Troy or avoirdupois. The pound was the so-called tower-pound, otherwise the easterling or sterling pound, less by ¾ of an ounce than the Troy pound. It was the pound of the mint long before the Norman conquest, and continued to be so for five hundred years after, or down to the time of Henry VIII. And the pennyweight, though equal to 32 wheat grains, corresponded to only 22½ grains Troy. The pound, by which at the same time wheat and wine were weighed, was a pound of 15 ounces, containing 6750 grains Troy. And the wine gallon, determined by the rule

above, was equal in capacity to 216 cubic inches, or 15 cubic inches less than our present wine gallon.

These particulars are mentioned only as an example of the confusion and want of scientific method, which has prevailed from the beginning in the legislation of Great Britain on the subject of weights and measures, and to illustrate the kind of chaos out of which has grown the singularly illogical system which we have inherited. Look for a moment at the irrationality of the series of ratios which connect the several denominations of weight: 24 grains make 1 pennyweight, 20 pennyweights make 1 ounce, 12 ounces make 1 mint pound, 15 ounces make 1 bread pound. We have these absurdities continued to this day, though with a slight modification of the numbers. But whatever may be the absolute values of the unit bases of a system, it is upon the ratios of the derivative denominations to these unit bases that the practical usefulness of such a system is mainly dependent. For purposes of calculation, the most advantageous of all possible numerical relations between these several denominations is necessarily the decimal, since the decimal ratio is that of the established system of abstract numeration. A metrological system founded on the decimal ratio requires no special instruction for its use. Our Federal currency perfectly illustrates that.

But next to the decimal in point of usefulness, though only next with a very vast difference between, will be a system in which the ratios, though not decimal, are at least uniform throughout, and among these the best of all will be one in which division takes place constantly by *two*. We have no such system. But look at what we have instead. Take our length measures: 12 lines make 1 inch, 12 inches 1 foot, 3 feet 1 yard, 5½ yards 1 rod, 40 rods 1 furlong, 8 furlongs 1 mile, 3 miles 1 league. Here is a series which could hardly have been made more irregular or inconvenient if confusion had been the express object in its construction. But it is by no means the worst. Look at the surface measures: 144 square inches make 1 square foot, 9 square feet make 1 square yard, 30¼ square yards make 1 square rod, 40 square rods make 1 rood, 4 roods make 1 acre, 640 acres make 1 square mile.

Look also at the measures of solidity: 1728 cubic inches make 1 cubic foot, 27 cubic feet make 1 cubic yard, 166¾ cubic yards make 1 cubic perch or rod.

The immense labor of computation which our unwieldy system

of metrology imposes upon all who are compelled to use it, renders reform of some kind a very urgent necessity. But whenever it has been proposed to change the values of our standard units the suggestion has never failed to excite earnest opposition, and to arouse something very like alarm. It has been represented as a thing too painful to think of, that a whole people should have such violence done to their habits of thought as to be forced to buy their beef by the kilogram, and their broadcloth by the metre. And yet the American who goes, as they say all good Americans hope to go, to Paris, accommodates himself in the space of about ten days to this frightful necessity, and is never conscious of any subsequent inconvenience. The reason is not quite clear why a good many Americans, that is to say, why the whole American population, might not do this with equal facility; since, though the inconvenience to the individual multiplied by the number of individuals in the country makes, it is true, a large total inconvenience, yet after all, each individual has only to do for himself alone what numbers of his countrymen do voluntarily every year.

Again, there arrive on our shores every week several thousands of persons of foreign birth, all of whom, except those from the British Islands, are total strangers to the system of weights, measures, and moneys which prevail here. These have to accommodate themselves forthwith to the state of things which they find existing; and we do not hear that it takes them long to do so. Even those from Great Britain find with us a system of measures of capacity totally different from that which they used at home. In the British House of Commons it was recently objected to the introduction into England of the Metric System of Weights and Measures, that the consequence of such introduction would be to reduce the size of the poor man's pot of porter. But our measures reduce much more seriously the poor man's pint of whiskey (he ought not to buy it, I admit, but he does) when he migrates from Lancashire or Galway to the hospitable shores of this great republic; and yet he comes all the same, notwithstanding.

Putting aside, however, for the moment the question whether a change in our unit bases of weight and measure is advisable or not, or whether it is even feasible, it may be claimed as true beyond all controversy, that our entire system of metrology ought without delay, to be radically reformed and reconstructed on a plan of decimal derivation. Evidence of the desirability or the necessity of

this makes itself manifest in the spontaneous efforts of many of the classes of persons who have to use our measures to free themselves from the inconvenience which the irregular derivation of the denominations occasions. Draftsmen and mechanical engineers who make the inch their unit, reject the *line* and divide the inch decimally. Topographers and civil engineers, who make the foot their unit, reject the inch and the line and divide the foot decimally. Land surveyors, who make the chain of 66 feet their unit—a very exceptionable unit by the way—still reject the foot and the inch, and divide the chain decimally. In the Mint of the United States, though the grain weight has not yet been wholly discarded, since by our statutes the weights of coins are expressed in grains, yet in the purchase of bullion, and in the deliveries of coins by the chief coiner to the Treasurer, grains are rejected, and the weights are expressed in ounces and decimals of an ounce. Moreover, in the standards of Troy weight constructed at the Bureau of Weights and Measures in Washington for presentation to the State authorities of the several States of the Union, the minor weights are all of them decimals of the ounce, and no grain weights are provided at all.

The exceedingly inconvenient structure of our present system of weights and measures being thus extensively recognized, it would seem as if the time had come when our Federal Legislature should take the matter in hand and give us complete reform. Such action might be had, leaving the unit bases what they are now—the pound, for instance, and the foot and the gallon. This would break up no old associations, and disturb no one's habits of thought; but, on the other hand, it would bring an infinite relief to all who have to deal with quantities, or to effect transformations of values.

But that such a reform as this is not at all the reform which the present writer believes should be undertaken, he does not hesitate very frankly to confess. Besides changing our system of derivation, we should change our unit bases themselves; or we should, at least, take now such preparatory measures, in view of future action of that kind, as to render the change when the time shall seem ripe for it, easy and acceptable to the people. The reasons for entertaining this belief will now be briefly stated.

It is not because the foot measure and the pound weight are not convenient magnitudes that I would discard them. They answer the purpose of unit bases very well; and if all the rest of the world

as well as ourselves were using them, I should desire that we might continue to use them also. And I will say further, that if there were any probability, even any possibility, that all the world could be induced to use them, let us test that probability, let us exhaust that possibility, before we give them up. Such does not seem to me to be the case.

Nevertheless, it does seem to be as certain as anything still in the somewhat distant future can be, that all the world will at length come into perfect harmony in regard to their systems of metrology; and this is an inference I draw, not merely from the past history of this subject, but from the strong tendency toward a common accord in regard to most matters interesting to man, which has manifested itself in modern times among all Christian nations. Upon this point I cite the following striking passage from the late Dr. Lieber, the highest authority we have had among us on matters concerning political and social science. "The modern nations of our group," says Dr. Lieber, referring to the group of Cis-Caucasian nations, "have arrived at agreement on many things, and this agreement goes on augmenting. We have the same alphabet, the same system of arithmetical and musical notation, the same division of the circle and of time, the same marine league, the same barometer, the same mathematical language, the same music and the same fine arts, the same system of superior and primary education, the same science, the same divisions of government, the same domestic economy, the same garments and the same fashions, the same manners, and the same toys for children (Asia and Africa have no toys—none at least for children only); we are united by a common system of posts and telegraphs; our tendencies are more and more to uniformity of measures, weights, moneys, and maritime signals; we have the same ideas on matters of finance, to such an extent that all the great Bourses of Commerce have become reunions having an international character, and an influence almost equal to that of diplomacy; we have an international law of literary property which is rapidly extending; a law of private property perfectly recognized abroad; in fine, a common international law, binding even in war. Add to this, that we have really one literature which may justly be called international, and in which a Shakspeare, a Kepler, a Franklin, a Humboldt, a Grotius, and a Voltaire, appertain truly to the whole Cis-Caucasian race; we have a common history of civilization, and Columbus as well as Francis,

Napoleon as well as Washington, appertain to us all, for our benefit or our misfortune."

There thus exists, and there has long existed a steady tendency toward uniformity of usages, uniformity of laws, uniformity of modes of thought, uniformity, in short, in everything which concerns the social state of man, among the entire group of Cis-Caucasian, or mainly Christian nations; and this tendency is gaining strength with every year in which the world grows older. Its operations have hitherto been tardy. "The history of simplification and unification," says Dr. Lieber, "is an uninterrupted history of difficulties slowly and progressively vanquished in the laws of succession and in general laws, in costumes, in measures and moneys, in a word, in all things." "In the middle ages," he continues, "the law of succession varied not only from one town to another, but even from one side to the other of the streets, since different populations had thus originally established themselves. This was the case at Rostock. Each place had its different measures, and its different methods of calculation; frequently the same place had different weights for different articles. The books of arithmetic in use in English schools give to this day, a frightful number of measures for different objects. Meantime uniformity gained ground, provinces established it, and finally whole countries introduced it into their laws, their measures, and their moneys. This is the point at which we have arrived in the matter, just as we have arrived at a nearly correspondant period in what concerns free trade. The principle of commercial liberty is to-day recognized universally and without restrictions, though in each country in an inconsequent manner by protectionists. Liberty of commerce exists in all the United States from Maine to Texas, from New York to San Francisco, but not beyond. The free-trader hopes that it will extend further, and overleap political boundaries, like measures, like moneys, like all standards."

Slowly, however, as the causes urging the nations onward toward uniformity do their work, they are accelerated in their action every year by powerful influences which are themselves the birth of a comparatively recent time.

One of these influences is that of our immensely improved facilities for transportation, alike by land and by water. Sixty years ago, a trip from New York to Boston was an affair of several days —a journey of hardly less than a week unless the traveller posted

day and night. Fifty years ago, a voyage between New York and Liverpool averaged a month in duration, and the arduous enterprise was undertaken only by here and there a daring adventurer. It is not beyond the recollection of many of ourselves, that a certain aureole of superiority used even, not so very long ago, to be felt to invest the individual who had courageously braved the dangers of the ocean voyage, and had safely returned to tell of the wonders of Europe. He was regarded as having fairly entitled himself to occupy in the social scale a higher platform than his untravelled fellow citizens. He belonged to a distinctly recognized order of republican nobility, and was complimented with the honorable title of Hajji. This, I say, seems not so very long ago; and yet, to-day how changed! The aureole has melted away, the traveller no longer bewilders with his glamour, and the order of republican nobility has sunk so low, that the title of Hajji is worth no more than that of a Polish count. In fact, this title, once so enviable, seems to have shared the fate of some of the academic degrees of which our American colleges have been so lavish—the laurel has ceased to distinguish on account of the vast multitude of the laureates. For it is almost the literal truth that we are all Hajjis now. New Yorkers, whose recollections extend back to the thirties in this century, will remember the irrepressibly mirth-moving story of Petrus Mudd, contributed, I think, by Mr. Verplanck to the Talisman. The hero of this tale, a respectable tradesman of this our good city of Gotham, was blessed with a spouse very capable of expressing herself with emphasis; yet it is recorded that when, on a certain morning, Mr. Mudd imparted to this good lady the intention he had formed of making a visit to London, the surprise with which she received the astounding information was so overpowering as absolutely to seal her lips. Yet if a New York merchant of the present day were carelessly to remark to his wife at the breakfast table, "I think I shall have to take the twelve-o'clock steamer for Liverpool to-day; throw me a few things together, if you please, in a carpet-bag," the answer would probably be, "Yes, dear," in the most quiet and indifferent manner conceivable. I suppose that there are in this city to-day more people who have circumnavigated the globe than there were, in the time of Petrus Mudd, who had visited England.

Now this enormous change in regard to habits of travel, true of other peoples no less than of ourselves, has been owing to the

immense improvements in the rapidity and comfort of transportation which have taken place within the last half century. The locomotive on the land, and the marine engine on the water, have so reduced the weariness, and the time, and the expense of travel, that the whole world seems to be constantly in motion. It is now just forty-five years since your speaker, then in the morning of life, came to make New York city his residence. In that year, one mail coach daily, and one daily small steamer sufficed for all the passenger traffic between New York and New Haven. The steamer was capable of conveying, possibly, an hundred passengers, but rarely carried more than fifty; the coach, fully packed, with two on the box, could carry eleven. Look at the contrast now, with trains arriving almost hourly, each bringing its thousands. And so it is abroad. A perfect network of railways binds together all the countries of the European continent. Rome and Vienna are but two days from Paris, St. Petersburg but three; and the trip to Berlin which the armies of Napoleon III., seventeen years ago, found so difficult, the peaceful traveller performs with ease in twenty-four hours. Enter the waiting-rooms of one of those continental railways and listen. The medley of tongues which were heard upon the day of Pentecost was not more marvellous, and you will be ready to exclaim with the astonished strangers on that occasion: "How hear we every man in our own tongue in which we were born, Parthians, and Medes, and Elamites, and the dwellers in Mesopotamia, and in Judæa, and Cappadocia, in Pontus, and Asia, Phrygia, and Pamphylia and Egypt?"

It is evident that the day has come in which many run to and fro, and in this much running it is inevitable that knowledge must be greatly increased. New peoples, who never see each other, and who know nothing about each other, it is evident can never be assimilated to each other in their manners or in their institutions. And peoples who know but little about each other, but know enough to know that they differ, are likely rather to persist in differing through prejudice, or a conceit of their own superiority, rather than to favor measures looking toward uniformity. With the free intermingling of peoples prejudices are rubbed off, as pebbles in the bed of a stream lose their angles by attrition; self-sufficiency finds less and less ground of justification, the peculiarities of other peoples become better known, and it begins to be seen that, after all, there is here and there something in them that is worthy of

imitation. International travel is thus beneficial to the cause of uniformity in a twofold manner: it prepares the minds of men first to desire uniformity, and teaches them, secondly, what is needed, in order that uniformity may be secured. And this cause alone, would probably suffice to bring the result to pass, if there were no other conspiring with it; for it is as impossible for people of different nationalities freely to intermingle through a long series of years without growing like each other in usages, in habits of thought and in institutions, as it is for differently colored fluids to mix without taking on at length a common tint.

Another influence tending in the same direction, is found in our modern improved system of postal intercommunication, both national and international. Early in this century our domestic correspondence was so heavily taxed that the post-office was little used by the mass of the people, except under the pressure of necessity. It is but about forty years, I believe, since Rowland Hill made the discovery, for it was a discovery, that the distance a letter is carried is of no consequence in settling the tariff, and that penny postage will pay better than shilling postage. Before that time the rates on foreign correspondence were almost prohibitory, and those on the home correspondence of this country were graduated according to distance. A letter to Richmond, Va., paid 25 cents; one to Washington, 18¾; one to Philadelphia, 12; one to Trenton, 10; one to Jersey City, 6. Taking the relative value of money at that day and this, these rates should be doubled. Now we send a letter to London for a nominal charge, less than then to Jersey City; or, considering the reduced value of money, for less than half the charge. The effect of this is to increase immensely the volume of international correspondence, and to break down correspondingly the barriers which keep nations in their feelings and in their usages asunder.

A similar influence is likewise exerted by the international lines of telegraph. If written correspondence, which, however rapid, lingers for days and weeks in the mails, contributes to draw peoples together, much more strikingly is this true of communications which are instantaneous. Astronomers tell us that the light which enters our eyes when we direct them towards one of the lesser members of the starry train, must probably have left its distant source years, scores of years, centuries, perhaps—who knows how long ago, and that, possibly, the star itself may have gone out, or have become a

red or a purple star since, and we none the wiser. Now, supposing that we have the assurance that that star is (or was once at any rate) the centre of a system of worlds like ours, inhabited by beings like ourselves, and that the luminous emanation which reaches us from it, is capable of bringing information of what the peoples of those remote planets are doing, we should, I think, receive this news with lively interest if we supposed it to relate to yesterday; but our interest would very sensibly diminish when we came to learn that the story it tells concerns something that happened about the time of the building of the pyramids. Instantaneous communications between peoples make men feel that they are contemporaries, and not members of different generations. More than that, they make men feel that they are living a common life and creating a common history, and that they belong not merely to the same generation but to the same great family. During the Napoleonic wars intelligence of the progress of events reached the United States from six weeks to two months after their occurrence. The battle of Marengo was fought on the 14th of June in the year 1800. It was not heard of in New York until some time in August. The treaty of Ghent, which concluded peace between Great Britain and the United States, was signed on the 24th of December, 1814. On the 8th of January following the British General Pakenham attempted to take New Orleans and was beaten, the General himself losing his life in the action. A useless and a bloody battle was thus fought a fortnight after the war was diplomatically ended. Had we years ago possessed no better means of international communication than existed in 1814, the capture of Sedan and the overthrow of the Second French Empire might have taken place before we had even heard of the declaration of war. How was it possible that nations should be closely drawn together, or should be actuated by living sympathies, when the simplest reciprocation of messages could scarcely be effected in less than three months? And how much more lively is the interest we are likely to feel—how much more lively is the interest we *do* feel in each other—now that every incident of importance which occurs in Paris, or London, or Rome, or St. Petersburgh is known in New York before the next hour is out!

The third influence to be mentioned, favorable to uniformity of usages, institutions, and standards, is that of the press. And here I intend not merely those ephemeral forms of publication which

constitute in political affairs the fourth estate of government, and which in literature, art, and science, keep constantly before us the impress of the living age. I mean no less the whole mass of contributions annually made to literature in its more permanent forms. For it is perfectly true, as Dr. Lieber has so well said, that the literature of the Ciscausian nations, whether produced in France or in Austria, in Italy or in Sweden, in Great Britain or in Prussia, on the banks of the Hudson or on the shores of the Mediterranean Sea, is a common literature, not only because it is the product of a common civilization, but in virtue of the fact that its constituent elements circulate freely throughout the whole extent of the common territory. To this free circulation even difference of language scarcely opposes a sensible check. The works of German, French, Spanish and Italian writers are freely read in England and the United States in their original tongues; and English or American works are read just as freely by the educated people of the continent. And, in addition to this, hardly a work of merit appears in any European language, which is not forthwith translated into every other. Now the effect of this in promoting the spirit which would bring nations into harmony in their usages, and especially in their modes of estimating quantities, is extremely powerful. For literature keeps existing differences in regard to these matters constantly before the minds of readers, and makes them to be felt, not as facts only, but as exceedingly troublesome facts, obscuring or making wholly unintelligible, passages otherwise of the highest interest. In the year 1867 there was published in Paris a little volume on weights and measures, the author of which, Mr. M. A. Péigné, had been led to undertake his task by an incident which he thus narrates in his preface:

"I resolved on the composition of this little work in a moment of vexation—see why. It happens frequently that journals and books speak of weights, and measures, and moneys, of which we know nothing at all of the values, as compared with ours. Why do they not indicate these relations? Probably the writers forget." [We may suggest on our part, probably the writers do not know.] "Take a simple fact among a thousand. I read a few months ago that a Russian army made a forced march of 206 versts. What then, I asked to myself, is a verst, and what is its value? It would have been very obliging in the author to insert this in parenthesis. I had then an idea. Though my labors of predilection have never

been calculations, I nevertheless applied myself immediately to the task of making this dictionary, convinced that I should perform a service useful to the public, in making known the relations of the moneys, weights, and measures of foreign countries with the moneys, weights, and measures of France. It was assuredly to undertake a labor completely inglorious, and of a monotony and aridity to drive one to despair."

If Mr. Peigné had waited a few years longer he might have dispensed with some pretty large chapters of his distasteful and thankless work; for since the publication of his book, all the kingdoms, electorates, principalities, grand dukedoms, petty duchies, and what not of Germany have been merged in one great empire, and their numerous and discordant systems of weight and measure have been shuffled off, to give place to the simple and beautiful system founded on the metre.

Had Germany but done as well with her coinage as she has done with her metrology, how far should we have been at this time advanced toward that ardently desired and earnestly to be prayed for social blessing, a uniform international currency.

(To be continued.)

NOTES ON LEAD-SMELTING IN SOUTHEASTERN MISSOURI.*

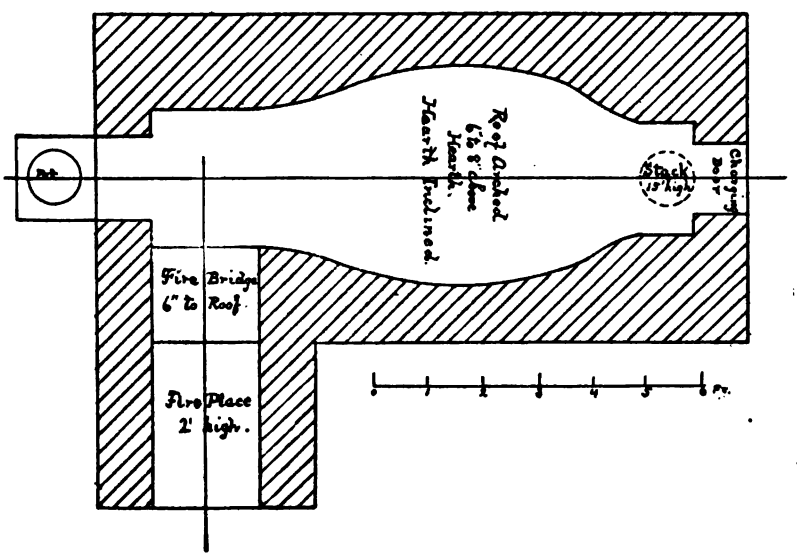
BY J. F. KEMP.

THE present conditions for lead-smelting in southeastern Missouri are widely different from those of the early days, or even from those of five or ten years ago. The historical development of the art from the first workings in the early part of the last century, is quaintly described in Schoolcraft's *Lead Mines of Missouri* down to 1819. Since then *The Mining Magazine;* Whitney's *Metallic Wealth of the United States;* the "Report of the State Geological Survey for 1873–74;" *Trans. Inst. Min. Engrs.*, vol. v., p. 315; paper by Prof. C. P. Williams, entitled "Some Points on the

* Compare paper in the QUARTERLY, vol. ix., No. 1, p. 74.

Treatment of Lead Ores in Missouri;" idem, February Meeting, 1888, paper by Prof. H. S. Munroe, on "The St. Joe Ore Dressing Mill;" G. H. Eldredge, Tenth Census, vol. xv., p. 809; Kleinschmidt, *Berg. u. Hütten. Zeitung*, Nov. 4, 1887; and numerous newspaper articles have made scattered references to the work. Mining at Mine la Motte (the first lead-mining in Missouri) dates from the grant of that property to Anthony Crozat by the King of France in 1720.

So long as the price of lead ruled above 5 cents per pound it was possible for the farmers throughout the region to mine, and in combination, to smelt or sell the galena at a profit, when their other work was dull. Since the advent of the three large companies referred to in the QUARTERLY, and the great increase in the production of lead in this country, the small producers, whether individuals or companies, have necessarily given up. A modern type of the small air-furnace was seen by the writer at Mr. Flood's in Summit, and is illustrated by the accompanying sketch. It was merely an inclined hearth, with the stack rising from one end, and a fire-place at right-angles with the axis of the hearth at the other.



Furnace 5 feet high of masonry and fire-brick, braced by rails; cast-iron door frame.

The problem before the metallurgists of the present works, is the smelting of a galena dressed from a dolomite, having with it

considerable pyrite which carries nickel and cobalt. This dolomite analyzes as follows:

	I. Monell.	II. Monell.	III. Neill.	IV. Potter & Riggs.
CaO,	28.04	33.79	30.91	29.84
MgO,	20.09	15.32	19.46	19.59
Fe_2O_3,	.....	6.80	.....	.....
Al_2O_3,	.....	0.08	.....	.....
SiO_2,	.....	3.77	1.27	2 96
$CaCO_3$,	50.0	.....	55.2	P, .006
$MgCO_3$,	43.9	.....	40.9	S, .091

I. Desloge tailings. II. St. Joe surface. III. Mine la Motte. IV. Same layer as the others, but further south, at Pilot Knob.

The rock as mined varies much in richness, and affords from 6 to 15 per cent. galena. The mills afford two general products, dressed galena the one, and a mixture of galena, pyrite, etc., locally called sulphides, the other.

	Pb.	Fe.	Co and Ni.	Cu.	Insol.	
St. Joe, dressed galena, Sept., 1884,	71.36	.....	.....	.....	.....	Setz.
Mine la Motte, Jan., 1881,	72.12	0.37	1.51	0.92	1.39	Neill.

More recent ones were from 70 to 75 per cent. Pb.

	Pb.	Fe.	Ni and Co.	S.	Insol.	
St. Joe sulphides, 1884,	21.87	16.21	0.61	.....	.....	Setz.
Mine la Motte, 1881,	17.17	.....	4.77	.....	.....	Neill.
" "	13.34	44.24	4.07	20.37	3.58	Neill.

These analyses vary widely. Those given show the general character. The Mine la Motte percentages of nickel and cobalt are above the average. In all the mills the dressed galena varies from 65 to 75 per cent. Pb. The sulphides are extremely variable, and are richest in nickel and cobalt at Mine la Motte. Mixed with these are necessarily varying amounts of dolomite, probably from 10 to 20 per cent. The treatment of the sulphides, which are the middlings of the ore-dressing processes, furnish a perplexing feature. If there were a cheap method of fine crushing adapted to such low-grade ores, it might prove serviceable in further differentiating galena and pyrite.

The dressed galena was formerly smelted in Flintshire, and air-furnaces at Bonne Terre, Scotch hearths at Mine la Motte, by the "Roasting and Reaction Process." The rich slags were afterward run through shaft-furnaces. At the time of my visit (1884) the

furnaces were still standing at Desloge, and were of the ordinary Flintshire type, but large examples.

The modern practice is to roast the dressed mineral in large Freiberg hearths, sinter with sand, and reduce in a shaft-furnace. The dressed galena and the sulphides are roasted separately. The roasters are from 60 to 66 feet long, 12 to 13 feet wide, and in the longer examples have ten doors on each side, with a discharge-door and a flue-door additional. The hearth slopes gradually from the stack until near the fire-place, and then more abruptly. The whole drop is about 20 inches. A roaster is estimated to cost $2500. A small dust-chamber is added at Mine la Motte. For the dressed galena the operation begins by shovelling in, at the two doors next the stack, 5000 pounds of mineral. This is carefully spread out with a large hoe, and occupies the space of two doors. The fire is meantime kept lowered. When the charging has been completed the fire is again raised. Previously to discharging the sintered material, sand has been thrown over the hearth next the bridge. The charge next this portion, having travelled the length of the roaster, is largely desulphurized, and contains not more than 5 to 6 per cent. S. It is now moved upon the hearth and spread out. Then each of the other charges is moved up two doors with long-handled steel spades, and turned over and rabbled with rakes and hoes, and a new charge is thrown in as at first described. All the doors are now closed and the fire urged to a high heat, and continued so until about two hours before the time for drawing the next charge. Meantime the ore is stirred up once an hour by long rods in the hands of two men, one on each side of the furnace. The proper amount of sand is now thrown in on the roasted charge and thoroughly mixed up with it. The fire is then urged to its utmost for two hours and the charge thoroughly sintered and fused. When the time for drawing comes, a half cylinder of boiler-plate is placed against the furnace-wall below the working-door, and sheltered by this the men hoe out with large iron hoes the fused and ropy mass. A little water thrown on it cracks it up and sledges make it fine enough to shovel. The operation of moving all up two doors and putting in

NOTE.—It was from beneath the sintering portion of the hearth that the crystals of silicate of lead were saved by Mr. Monell, and described in the Am. Jour. Sci., Aug., 1885, and Oct., 1886, by Prof. H. A. Wheeler of Washington University, St. Louis, and Prof. E. S. Dana.

a fresh charge is then repeated. Each charge is in the furnace 36 hours. About four cords of wood are burned per day. Occasionally by the raising and lowering of the fire a slight "roasting and reaction" takes place and some metallic lead is formed. This is allowed for in construction, and as the ash-pit comes at the lowest part of the furnace the lead trickles in thither and is removed with the ashes. These are washed and the lead separated.

The following are some analyses of the roasted mineral:

	Pb.	FeO.	SiO_2.	CaO.	S.		
Desloge, ...	64.3	3.70	13.09	1.9	6.0	Hoffmann.	
St. Joe, Sept. 13, 1884, . .	69.3	.....	.....	.....	5.68	Setz.	
"	69.62	.....	.....	.....	4.23	"	
		Fe.					
Mine la Motte, Dec. 30, 1880, .	71.85	3.02	2.80	2.25	7.12	Neill.	
						Co & Ni.	
" " May 31, 1881, .	75.95	4.5	7.21	0.76	7.41	1.11	"
						Insol.	
" " Nov. 1, 1881, .	69.77	6.12	.....	.....	4.24	8.12	"
" " Jan. 1, 1882, .	72.73	4.24	.....	1.94	4.35	6.12	"
" " May 15, 1884, .	68.40	5.60	.....	.....	4.71	8.92	"

The roasting of the sulphides is a much simpler process. They are shovelled in, one-half to one-third the way down from the stack, and only put through the remainder of the hearth. There is no sintering with sand, but the ore is drawn when it reaches the end of its course. When the charge is drawn the rest is moved up one door at a time. The following are some analyses of roasted sulphides:

	FeO.	Pb.	CaO.	S.	Ni & Co.	MgO.	Cu.	Insol.	
Desloge, . .	22.36	.....	10.34	11.00	.....	.....	.....	.....	Monell.
	Fe.								
St. Joe, . .	16.63	15.42	34.18	6.36	.....	17.83	.....	.....	Setz.
" . .	21.91	30.74	16.25	8.96	0.98	8.11	.....	.....	"
" . .	23.83	18.46	.....	7.41	.....	.....	.....	.....	"
Mine la Motte, .	44.37	12.58	3.57	7.12	4.07	1.25	0.97	.....	Neill.
" " .	17.50	28.00	3.00	9.50	5.30	1.65	10.33	14.19	"

These analyses illustrate the variable nature of the sulphides. In the Mine la Motte analyses the percentages of nickel and cobalt are above the average as noted above. The roasted ore is hauled to the cupola and there reduced. In a word, the operation to be performed here is the reduction of roasted "mineral" containing 65 to 75 Pb, 3 to 6 FeO, 7 to 13 SiO_2, a small percentage of CaO, and 4 to 7 S. With this are varying though small percentages of

MgO. At the same time, the "sulphides," containing from 20 to 25 FeO, as high as 30 Pb, 3 to 34 CaO, 6 to 11 S, as high as 18 MgO, with some Ni and Co—and at Mine la Motte some Cu—are to be worked in; also roasted mattes, obtained as subsequently to be described in the course of reduction. The cupolas are of the circular type, with a crucible and siphon-tap for the lead, and an intermittent tap for the slag. They have water-jackets with a bosh, five or six tuyeres, a fire-brick ring for a few feet above the water-jackets, and then a boiler-plate cylinder lined with fire- and red brick, these latter being supported on iron pillars. The total height of the furnace is 30 to 40 feet. The general dimensions are: crucible, 2′; from top of crucible to base of water-jackets, 5″ to 6″—in this is the slag-tap; water-jackets, 3′ 6″ high, with a bosh 1″ to 3″, according to the character of the ore. The bosh is continued to the charging-door. From tuyeres to charging-door, 8′ to 10′ 6″; diameter at tuyeres, 4′ 3″ at Bonne Terre, 3′ 9″ at Mine la Motte. Baker blowers No. 5½ are preferred for the blast, of which the pressure is 1 to 1½ inches mercury, according to the action of the furnace.

There are two different kinds of smelting, one for the production of lead and first matte, and one for the concentration of first, second, and third mattes after they have been roasted. This last is for the cobalt and nickel. They differ in that puddle cinder is employed as the iron flux in the first, roasted matte in the second. The charge is calculated so as to give a slag of the general formula, 40 FeO, 30 SiO_2 and 20 CaO, the remaining 10 being allowed for Al_2O_3, etc. These figures are somewhat altered in practice, as will be seen from the analyses; but in all cases after the furnace has become well started and is familiar to the metallurgist, he relies on the appearance and physical properties of his slag, corroborating his conclusions by an occasional analysis. Having calculated the slag, enough more iron is added, which when reduced will give a matte of the formula FeS with the S. Coke forms from 10 to 15 per cent. of the charge. On a 65 per cent. ore a cupola of this character is capable of turning out from 350 to 500 85-pound pigs refined lead per 24 hours. Considerable subsulphide of lead is formed with the lead, and necessitates subsequent refining. From the lead-well there is a constant dribble into an auxiliary pot, whence it is ladled into the pig-moulds.

The matte and slag are tapped together into conical slag-bar-

rows at intervals of about 15 minutes, or as fast as a potful accumulates. The matte separates at the bottom and is knocked off and saved. In the first use of the cupola the lead and matte were tapped together into a sump, and the matte removed from the lead on cooling by hooks. The slag was then run from another spout over an inclined face, broken up with water, and shovelled away. The introduction of the Ahrents siphon revolutionized this barbarity.

The mattes obtained from this operation are called first mattes. They are hauled away and roasted in piles at Bonne Terre, but at Mine la Motte in a Freiberg hearth, that no nickel and cobalt sulphates accidentally formed be leached out by the weather. These piles are locally called kilns. They are approximately 40′ long, 15′ wide, and 4½′ high. After being suitably roasted the matte is used, as stated above, as an iron flux, and after being run through for the third or fourth time, the nickel and cobalt becomes high enough to be profitably shipped abroad.

The following are slag analyses:

Reduction Slag.

	SiO_2.	Al_2O_3.	FeO.	CaO.	MgO.	PbO.	
Desloge, . .	34.6	5.3	39.3	11.0	6.9	.....	J. T. Monell.
" . .	33.74	4.81	38.93	13.00	8.50	.....	"
St. Joe, . .	32.81	3.06	38.69	16.26	8.95	0.52	Setz.
" . . .	34.36	2.43	39.37	15.24	7.58	0.37	"
Mine la Motte, .	35.3	5.56	35.9	13.9	9.27 (est.)		Neill.

First Matte Slag.

	SiO_2.	Al_2O_3.	FeO.	CaO.	MgO.	Pb.	Ni & Co.	
St. Joe, . .	31.41	2.13	48.58	11.43	4.88	.....	0.81	Setz.
Mine la Motte, .	28.2	7.1	40.0	11.4	6.00	1.5	1.7	Neill.

Second Matte Slag.

	SiO_2.	Al_2O_3.	FeO.	CaO.	MgO.	Pb.	Ni & Co.	
Mine la Motte, .	35.27	19.75	36.36	14.14	9.43 (est.)	1.74	0.71	Neill.

Third Matte Slag.

	SiO_2.	FeO.	CaO.	MgO.	Pb.	Ni & Co.	
Mine la Motte, .	39.34	22.38	18.53	12.28 (est.)	2.22	0.98	Neill.

The unrefined lead cast from the cupola is taken to the refiner, to be relieved of the subsulphide of lead, etc. The refiner is a basin of cast-iron set into the hearth of a small reverberatory. The men fire up about 5 A.M., and throw wood in the pan. When the fur-

nace is well heated they put in the pigs and throw cord-wood on top. When this burns out and the charge is well melted, one of the men, with a round perforated piece of sheet-iron on a long handle skims off the dross, consisting of subsulphide, oxide, and metallic lead, mixed up with charcoal, ashes, etc., and another taps the lead through a spout with a plug into the moulds. The head refiner skims off the pigs before they cool with two pieces of pine shingle, leaving them smooth and bright, but with a brilliant iridescent tarnish peculiar to the brand. The skimmings are sent back to the cupola and charged in with the other materials. The above is the refining as practiced at Bonne Terre. At Mine la Motte it is different. The pigs are melted in a small reverberatory, but as soon as fused are run into a large kettle precisely like a zinc desilverization kettle, holding 18 to 20 tons, and there poled by a steam-jet and cast through a Steitz siphon. This gives a very small amount of skimmings and a very clean-looking lead, which is sold as the anchor brand. All the Missouri brands are thought to be especially well adapted to the lining of sulphuric acid chambers at chemical works, and for lead pipe.

Mr. Neill's * retreatment of nickel and cobalt mattes by the aid of the speiss from desilverization works has already been published, In brief, he ran his nickel-cobalt-lead mattes through a small cupola with argentiferous and auriferous speiss, obtaining a nickel-cobalt speiss, a matte with some lead, and a very hard lead with the silver and gold.

Mr. Setz, at St. Joe, has of late treated a portion of his ore in a ten-tuyered Scotch eye, in such a way as to make but 30 per cent. lead. The fumes were then sucked by a Sturtevant blower through an Ems condenser, and then forced through a wooden tower filled with blocks of wood, through which trickles gently a continuous stream of water. The gray slag is returned to the cupola and there smelted with the other ores. This was to obviate in part the expense of Freiberg roasters.

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* Neill, J. W., Amer. Inst. Min. Eng., 1884–85, p. 634.

THE VALUE OF WATER-POWER CONSIDERED IN RELATION TO INDEMNITY TO RIPARIAN OWNERS WHEN THE WATER OF A STREAM IS TAKEN FOR PUBLIC USE.

BY W. P. TROWBRIDGE.

In communities where population is rapidly increasing, the real or fancied needs of the public frequently demand the taking of private property for public uses; and while it is universally recognized that compensation is due to private owners for property thus taken it can hardly be said that the rules or processes provided by law for adjusting the measure of compensation result uniformly, or even ordinarily, in doing fair and full justice. In too many cases, indeed, individuals are despoiled ruinously, and left without a hope of redress. Such cases are, perhaps, exceptional; but others are of constant occurrence in which the costs of the proceedings are often so great in comparison with the value of the property involved that the results amount almost to confiscation. In enlightened communities this is, of course, not intentional, but arises rather from the difficulties which are encountered in estimating values, and losses or damages to the private owner; and not infrequently from errors of judgment on the part of those who may be appointed to determine the causes. Quite as often, too, errors are committed through mistakes and differences of opinion on the part of experts who are relied on to aid the authorities in arriving at equitable conclusions.

Of all classes of property, that which has perhaps presented the greatest perplexity, and given rise to the most varied decisions, is the property involved in the recognized right of the owner of land through which a stream passes to the reasonable use of the water of the stream, and especially to its use for power where the conditions exist for thus utilizing the water. A great number of such cases has arisen in this country where individuals own land on both sides of streams of such magnitude that, with the means and facilities at their command, they may so far utilize the water of the streams that, if a part or the whole of the water be held back or withdrawn, their facilities for power are destroyed or impaired. Many of these cases have occurred where cities or towns have

required water for sanitary purposes, and where legislatures have authorized the taking of water from streams passing through private lands, and which supply to the private owners of these lands facilities for making use of the water for manufacturing purposes. Another class of cases is found where the private lands, as well as the water rights which they embrace, are taken for public uses. The principal question which then arises, as far as the streams are concerned is, what inherent or added value is to be placed upon land by reason of the facilities which flowing water and topographical features of the channel afford to the owner as essential elements of water-power?

In nearly all cases the questions involved require the consideration of the money value of water-power, and in most instances of the character which it is proposed to discuss, neither questions of law nor questions of facts can be at present referred to undisputed precedents or principles. Courts, commissions, and juries do not always have a correct statement of facts before them, especially in regard to the quantity of water flowing in any given stream. Expert evidence on these points may be as variable as the flow itself, unless all expert witnesses place themselves upon a common plane, or origin, to which their views and deductions may be coördinated. Diversity of opinion and practice on the part of experts adds to the embarrassments of the courts, and doubtless often causes expert evidence to be looked on with little respect and confidence.

Questions of indemnity are, it is presumed, based upon assumed facts, and when such assumptions are inherently defective or untrue, as often happens in the class of cases to which I have referred, it is not surprising that the remark should be made by an observer of great experience in practical hydrology that: "The courts and legislatures of manufacturing states have wrestled with this question, their judges have grown hoary while they pondered it, and their attorneys have prospered; yet who shall say what riparian rights shall be until the court has considered all anew?"

It is not to be presumed that the difficulties of the subject can be completely removed, but much may doubtless be gained through a better popular understanding of the causes of these difficulties, and some definite agreement on the part of engineers in regard to the true basis of all hydrological investigations, such as are involved in this subject.

As illustrations and discussions may be rendered more clear by an example, we will take a stream in, or adjoining, the Croton basin, having a water-shed of 50 square miles. Numerous factories and mills have been established at certain points on this stream by individuals owning the land on both sides of the stream; while at other points, although all the requirements of water-power exist, the power has not been, or is not utilized; that is to say, the topography of the ground causes what are known as water-falls at various points, which, by means of simple dams across the stream, may furnish all the facilities for the introduction of hydraulic motors and the erection of manufacturing establishments; in some cases with considerable storage capacity above the dam, and in others with little or none. It is assumed that in many instances such water privileges have been improved and are in successful operation, while in others the owners have not yet introduced improvements which, at their discretion, are at any time practicable. It is further assumed that, by authority of the Legislature, the city of New York takes possession of a portion of this stream at its upper part, and builds a dam by which all the water above is cut off from the owners below, and is diverted to the city.

In other cases lands through which the stream runs, and on which are corresponding water privileges, is taken for public use, depriving the owners not only of their property in the land, but also of the value, whatever it may be to them, whether present or prospective, of the water privileges arising from the existence of the stream and the topographical features of the ground, which together produced the water-falls.

The question which will immediately arise in the mind of every one is: "How is a proper and fair compensation to be determined in both cases?"

Considering only the compensation due for loss of power the obvious answer to the question would suggest itself: viz., first ascertain the value of the whole water-power available to any particular owner, and then remunerate him for the proportion which is taken from him.

But the difficulties here begin. By what process of investigation is the whole value of his water-power to be ascertained? Many kinds of property have what is called a market value; and it is a common practice, I believe, in judicial proceedings where the value of certain kinds of property is in question, to call upon persons

for advice or information, whose dealings in such property enable them to furnish fair estimates of its money value. Water-power is not property of this character; even within limited districts this property does not change hands frequently; and, moreover, there are so many incidental circumstances that make a water privilege in one locality more valuable than another of the same capacity not far distant, that a comparison of the two on the basis of market value could hardly be made. For stronger reasons there can be no relation between the money values of water-powers widely separated.

It might be argued that the price at which water-power is sold in different places may be taken as a gauge of its value. This proposition would appear at first sight to be almost unanswerable; but a little consideration will show, I think, that the value which is contemplated when an individual is deprived of water-power on his own land, and which he has perhaps utilized, ought not to be measured by the price at which some other individual or corporation owning water-power may be willing to sell power. Such corporations often make the sale of power merely a means of attracting manufacturers, while the principal object of the corporation is the sale or lease of land. Furthermore, an individual or company may possess such remarkable facilities for water-power, in natural lakes for reservoirs, and precipitous falls which require very little expenditure for dams, that they can well afford to place a very low price on the power sold. It would be unreasonable, I think, to hold that the existence of such remarkable facilities in one place limits the rights of an individual owning water-power in another place.

The following table gives the cost per horse-power of water-power at some noted localities in this country.

A glance at this table shows that there is no law governing the prices at which water-power is sold, but that these prices vary greatly, and apparently with the special circumstances and conditions connected with the different sites or localities where they are established. In Maine, for example, there are numerous lakes, some of them very large, which store immense quantities of water; and dams built at small cost upon the outlets of these lakes furnish large water-powers. In some instances it appears that water-power can be sold at a profit at the low prices given in the table. In other regions, and especially where many of the large improved

water-powers of the country are situated, it is probable that if the sale of power were the only source of profit, the prices at which it is sold would not be remunerative.

PRICES PAID FOR WATER-POWER AT CERTAIN PLACES IN THE U. S.

(From Vol. XVI, page 35, of the Reports of the Tenth Census.)

PLACE.	STREAM.	MINIMUM POWER IN HORSE-POWER.	COST PER ANNUM.
Lawrence	Merrimack.	11,000	$14.08
Lewiston	Androscoggin.	12,000	1.87 to $9.37
Windsor Locks	Connecticut.	17,000	13.50
Bellows Falls	"	12,000	7.50
	Shelucket.	290	20.00
Barrett's Island	Swift.	200	9.00
Birmingham	Housatonic.	1,375	20.00
Cohoes	Mohawk.	9,450	14.67
Niagara Falls	Niagara.	4,000,000	7.00
Passaic	Passaic.	800	33.33
Paterson	"	2,150	36.00
Trenton	Delaware.	4,000	37.50 to 50.00
Franklin, O.	Miami.	600	29.37
Dayton, O.	Mad.	270	36.71
Appleton, Wis.	Lower Fox.	10,200	Power leased with necessary land for 500 to 1000 H. P., $1.00 to $2.00; lease of land with 100 to 300 H.P., $3.
Lawrence	Kansas.	2,250	$20.00.

The intrinsic value of a water-power to the owner who improves and uses his own power is practically inversely as the cost of the works necessary to utilize the power. Where the cost of such improvements amounts to but little more than the cost of the motors, expensive dams being unnecessary and other things being equal, the intrinsic value to the owner is a maximum; and, although he might be able to sell power with profit at a very low price, yet the value to him is the saving effected by reason of the small cost of his power compared with any other power—steam, for instance—which he would otherwise be obliged to employ.

It seems to be unavoidable, therefore, for the purpose of a fair and just estimate of compensation, that the actual power available to the owner should be ascertained by some process which shall determine as truly as the science of hydrology may permit, the actual available amount of power which he is able to utilize; and

then to compare the actual cost to him of this amount of power with the cost of steam-power, which is generally the only practicable substitute. The difference in such cost yearly may be assumed to represent the value to the owner of his water power; a value which arises from his ownership of landed property embracing the peculiar features of flowing water and topographical depressions, which constitute the elements of water-power.

If these premises be admitted, we come now to a series of questions, the determination of which in different cases has been a source of perplexity and confusion. The main question is, *How shall the available power at any mill site be determined?*

The secondary questions are: 1. Is there a substantial concurrence on the part of hydraulic engineers in regard to the exact methods to be pursued? 2. Is there a substantial concurrence on the part of such engineers as to the actual money value of the power which each may in his own way have decided upon as the available power? 3. Where an owner of a mill-site is not utilizing as fully as he might the available power, or perhaps not using it at all, can he equitably be refused full compensation, on the ground that he is not availing himself of his rights and privileges at the time when a part or the whole of the water is diverted from his stream?

4. When his land is taken for public purposes, does the existence of a valuable water privilege on the land furnish to the owner a basis for a demand for additional or added compensation over what the land may be valued at for ordinary purposes?

The last two propositions, and doubtless others which might be mentioned, involve perhaps important questions of law which do not come within the province of the engineering expert; but he is obliged to assume, in the absence of authoritative decisions or instructions, that the owner has certain rights, otherwise his investigations and labors could have no aim or object.

The main question, "How shall the available power at any mill site be determined?" I propose to discuss from the assumed point of view that it relates to the full and ultimate rights of the property-owner, and is not coupled with any question of expediency; that whether he uses all of his available power or not, he is entitled to what he may utilize by reasonable and customary practices and arrangements.

This distinct understanding is necessary because, in general pub-

lished statements of the available power of streams throughout any district or country, it is usual to state what power a given stream will furnish when the least flow for several weeks, or for a month, without storage, is taken as a basis of estimate; again, when the least average summer flow is taken as a basis, without storage; and again, when in both cases storage is considered. Such statements for public information are not only expedient and proper, but are the only practicable modes of furnishing statistical information when details in regard to particular sites are not included. The force of these conditions will, I think, be apparent, when the meteorological, hydrological, and geological circumstances and conditions which are concerned in the flow of streams are fully examined.

The quantity of water which flows daily in any ordinary stream depends primarily upon the amount of rainfall upon its water-shed and upon the distribution of the rainfall throughout the year.

Next in importance is the general topography of the water-shed and its geological characteristics. Steep hill-sides with little surface-covering to the rocks, permit the rain-waters to flow off rapidly to the streams. In such cases the variations in the flow of streams in the valleys follow almost immediately the variations in the rainfall; and, owing to the small losses due to evaporation and percolation, the proportion of rain that flows in the surface-streams is always large.

Again, where the surface of a water-shed is level or gently undulating, and covered with a retentive soil, where pastures, meadows, and marshes exist, the rate of flow to the streams is slow, and more of the rainfall disappears beneath the surface, or is taken up by vegetation, or evaporated. The existence of natural lakes within the water-shed has also an important influence.

On some water-sheds of great extent, as, for example, Long Island, and considerable portions of some of the Western States, the sandy and gravelly nature of the surface and sub-surface alluvium, or drift, permits a large part of the rainfall to percolate at once downward; and the surface-streams are few in number and small, while those which do exist are not liable to so great fluctuations as streams in hilly, rocky regions. Even on quite limited water-sheds the underground flowage is often greater than the flowage of the streams, owing to the loose gravelly or sandy character of the soil to considerable depths.

The proportion of the rainfall that reaches the adjacent streams

of a water-shed, while dependent upon the amount and distribution of rain throughout the year, is thus largely and, perhaps, mainly influenced by these local characteristics of topography, geology, climate, and vegetation.

To illustrate the variations of both the rainfall and the flow of streams, the following diagrams have been prepared. They will also serve to point out certain laws of the flow of streams in connection with the quantity of water that may be rendered available by storage, to which I desire to call attention. The first set of diagrams, numbered from 1 to 12, is designed to exhibit variations of rainfall. They are reproduced and enlarged from a set of diagrams published in the Connecticut Almanac for 1887, edited by Prof. A. W. Phillips of Yale College. The original diagrams were prepared by Mr. D. T. Sherman, who was connected at the time with the astronomical observatory of Yale College.

Systematic and continuous observations of rainfall have been made at Yale College for nearly one hundred years, and these observations are here represented for twenty-four successive years.

The first diagram shows the rainfall for January of each year, one inch of the scale corresponding to one inch of rain. The diagram shows at a glance the variability of the January rainfalls for the years 1861 to 1885.

The second diagram exhibits the variability of the February rainfalls in the same manner, and so on for each of the twelve months in the year.

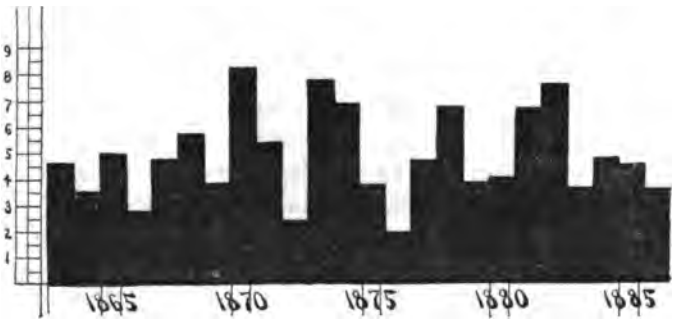
It is interesting to note the greatest and least rainfall for the different months in this series, as shown in the following table:

Extremes of Rainfall for Different Months.

	Min. Inches.	Max. Inches.
January,	1.9	8.2
February,	1.3	7.0
March,	1.8	11.7
April,	1.5	7.3
May,	0.7	6.8
June,	0.5	8.0
July,	1.4	11.2
August,	1.0	13.0
September,	0.5	11.6
October,	0.9	15.5
November,	1.8	7.3
December,	1.2	8.3

January

1 inch vertical scale = 1 inch of rain = 53.03 cu. ft water per min. per month

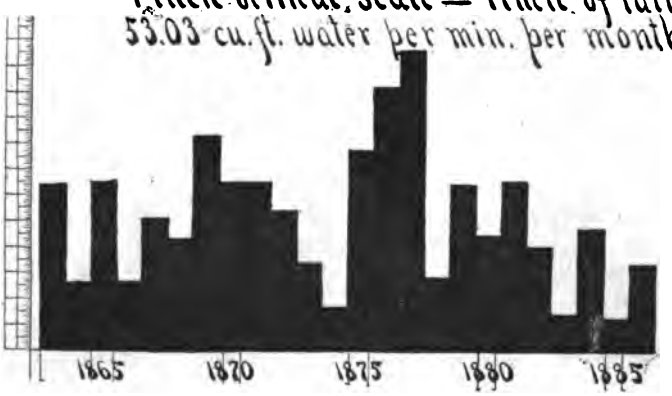


February

1 inch vertical scale = 1 inch of rain = 53.03 cu. ft. water per min. per month

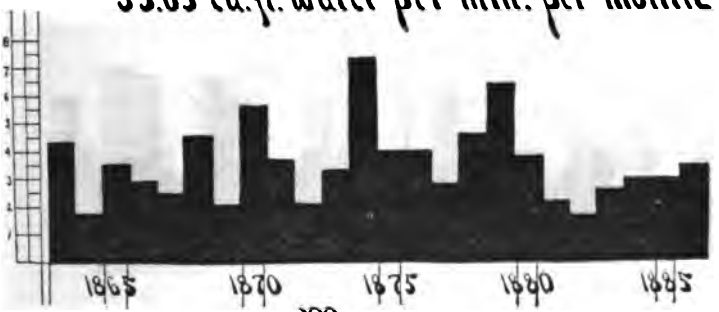
March

1 inch vertical scale = 1 inch of rain = 53.03 cu. ft. water per min. per month



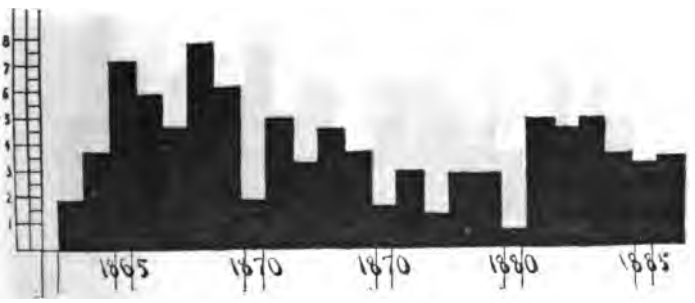
April

1 inch vertical scale = 1 inch of rain = 53.03 cu. ft. water per min. per month



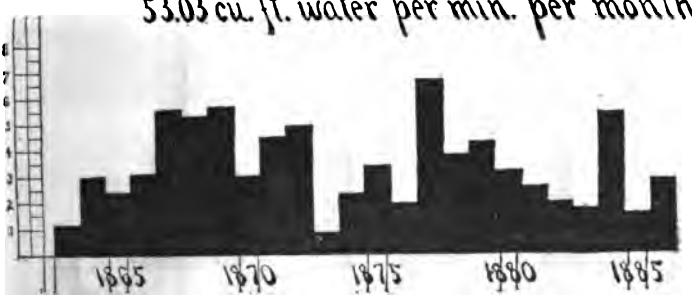
May

1 inch vertical scale = 1 inch of rain = 53.03 cu. ft. water per min. per month



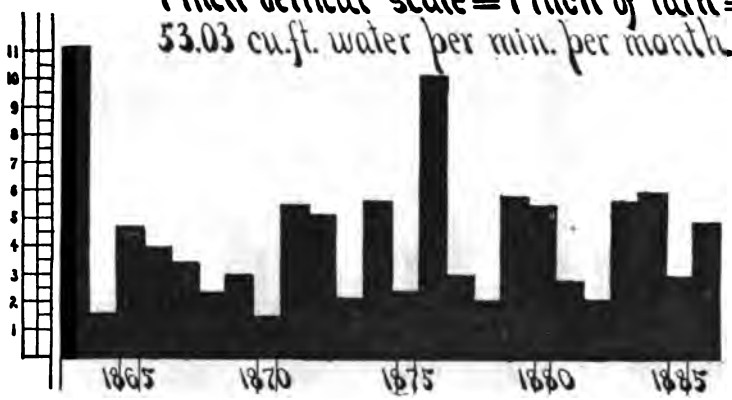
June

1 inch vertical scale = 1 inch of rain = 53.03 cu. ft. water per min. per month.



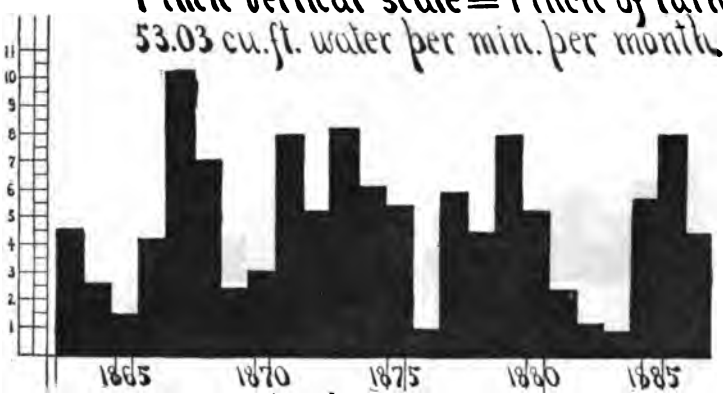
July

1 inch vertical scale = 1 inch of rain = 53.03 cu.ft. water per min. per month.



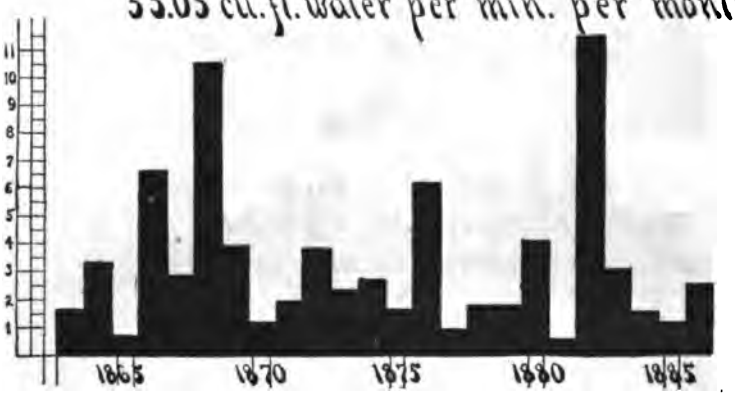
August

1 inch vertical scale = 1 inch of rain = 53.03 cu.ft. water per min. per month.



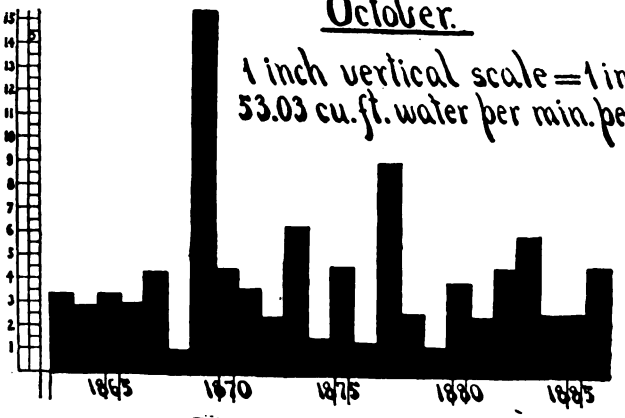
September.

1 inch vertical scale = 1 inch of rain = 53.03 cu.ft. water per min. per month.



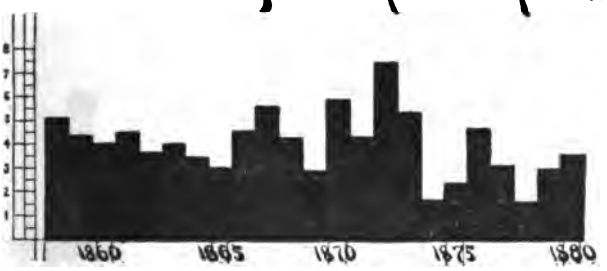
October.

1 inch vertical scale = 1 inch rain = 53.03 cu. ft. water per min. per month

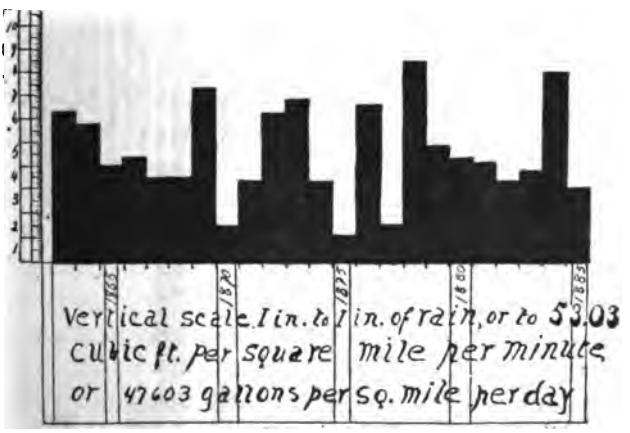


November

1 inch vertical scale = 1 inch rain = 53.03 cu. ft. water per min. per month



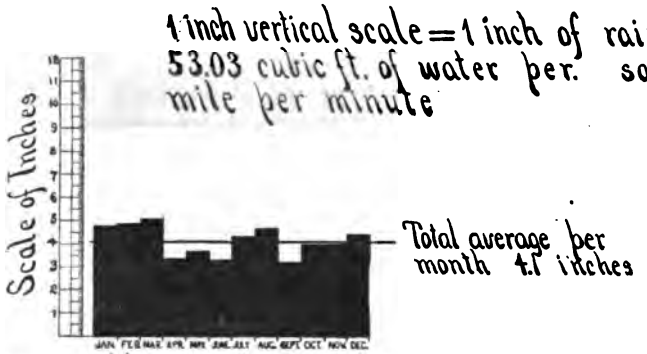
December.



The greatest variation occurs in October, as will be seen in the diagram for October, the least October rainfall being less than one inch and the greatest over 15 inches, while the least variation is in November.

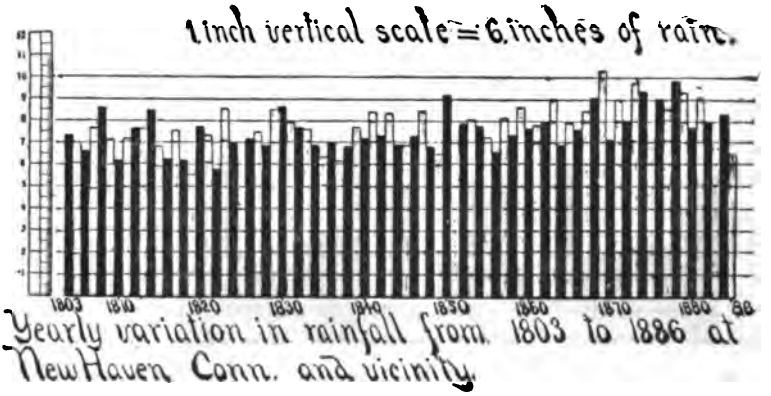
The next diagram (Diagram 13) is constructed by taking the means or averages for the different months. Thus the average

DIAGRAM 13.


1 inch vertical scale = 1 inch of rain = 53.03 cubic ft. of water per. sq. mile per minute
Scale of Inches
Total average per month 4.1 inches

Average monthly rainfall in inches for a period of 24 years at New Haven, Conn. and vicinity.

DIAGRAM 14.



Yearly variation in rainfall from 1803 to 1886 at New Haven Conn. and vicinity.

January rainfall for the period covered by the observations is 4.75 inches, the average for February is 4.8, and so on.

This diagram brings clearly to view the fact that the average rainfalls for the different months of the year do not differ in a very

remarkable degree. If we except April, June, and September, there is a near approach to uniformity; and for these months the diminution is not excessive.

The last diagram of this series (Diagram 14) shows the yearly variations of total rainfall for the years 1805 to 1885, in the vicinity of New Haven. According to this diagram the total yearly rainfall has been slowly increasing in that vicinity.

We come now to the question of the flow of streams. No observations are available for the flow of streams in the vicinity of New Haven which might be compared with the rainfall; but such observations, together with the rainfall, have been made for the Croton water-shed, from which the supply of water for New York is drawn.

Mr. J. T. Fanning, in his admirable work on the "Supply of Water to Towns," gives tables showing the average monthly rainfalls for a series of years on the Croton basin, and also the average monthly flow of streams for the corresponding series of years, which agree closely in the aggregates with the most recent determinations of the Department of Public Works of New York City. The following diagram has been constructed from Mr. Fanning's tables. It shows the average monthly rainfall for a long series of years, with the corresponding flow of streams, from observations made under the auspices of the Department of Public Works, and is probably the most reliable presentation that we have at present of these phenomena for any stream on this basin. The diagram begins with the month of November and runs through the twelve months. It is impracticable to discover any definite law connecting the flow of streams with the rainfall, further than that presented by the diagram. This might have been expected since the quantity of rainfall which flows off by the surface-streams is subject to such a variety of conditions. All that can be said is that the diagram exhibits the variations of flow of streams and rainfall peculiar to the Croton water-shed, and is not applicable necessarily to any other water-shed. Nor would a similar diagram for a water-shed, differing from that of the Croton, in climate, meteorology, geology and topography be applicable to the Croton.

In this diagram (No. 15) one division of the horizontal scale represents a month, and one inch of vertical scale represents for one month a rainfall and flow of streams equivalent to 20 cubic feet per minute per square mile. This corresponds to 0.3773

inches of water covering one square mile. For twelve months, or the whole extent of the diagram horizontally, one inch of vertical scale corresponds to $12 \times 0.3773 = 4.53$ inches of rain on a square mile. The *average flow* for the whole period of

DIAGRAM 15.

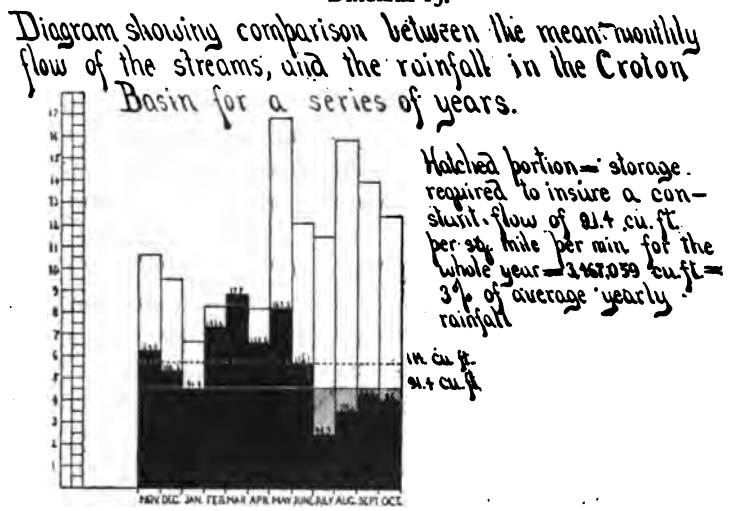


Diagram showing comparison between the mean monthly flow of the streams, and the rainfall in the Croton Basin for a series of years.
Hatched portion = storage required to insure a constant flow of 91.4 cu. ft. per sq. mile per min. for the whole year = 3,467,059 cu. ft. = 3% of average yearly rainfall
in cu. ft.
91.4 cu. ft.
NOV DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT

DIAGRAM 16.

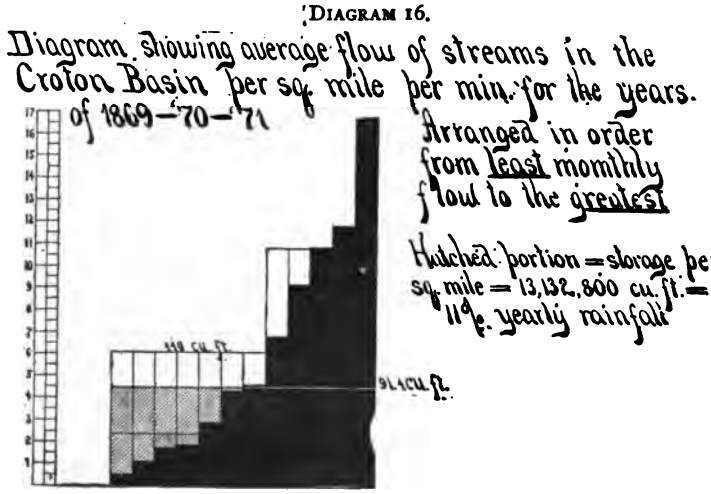


Diagram showing average flow of streams in the Croton Basin per sq. mile per min. for the years of 1869–70–71
Arranged in order from least monthly flow to the greatest
Hatched portion = storage per sq. mile = 13,132,800 cu. ft. = 11% yearly rainfall
91.4 CU. FT.

twelve months is equivalent to 114 cubic feet per square mile per minute.

We are now somewhat prepared to consider some of the questions which it is the object of this paper to discuss.

1st. In determining the *available* flow of a stream, or in other words, the proportion of the total average flow which may be utilized, for the purpose of ascertaining its value to an owner for water-power, should these monthly averages for a series of years form the basis of the estimate, or should a year, or a series of two or three years of low rainfall and diminished flow be taken? This is the first question on which experts must agree. One expert might base his calculations on the averages of a series of years, and another upon one, two, or three years selected arbitrarily, and their results, however correct might be the calculations, would be wholly irreconcilable. For the purpose of estimating the supply of water to a town it is recognized as a proper rule to ascertain the available flow, and the necessary pondage to secure it for the driest years, when there is any doubt of there being sufficient capacity in the stream; because the supply of water to a town must not fail, even in the driest years. But this rule can in no way restrict or govern the rights of a riparian owner. It is merely a measure of prudence, wisely adopted for the benefit and safety of a town.

My own view is that experts should look for the fullest measure of flow that can be rendered available, taking the longest series of years for which observations are at hand; and that against such a series of years and of observations, no arbitrary selection of a year or of several years of deficient or excessive rainfall and flow should be allowed to stand in evidence.

Diagram No. 16 shows the flow of a stream in the Croton basin for a series of three years, 1869, 1870, and 1871. This series includes one of the driest years of the century, and another in which the summer rainfall was deficient, and the winter rainfall excessive. If these years were selected, for example, they would afford no gauge of average conditions, but would place the owner at the unfair disadvantage of very dry summer seasons and excessive floods in winter, which are only exceptional cases.

The next step in regard to which opinions may differ is perhaps more difficult. What proportion of the average flow for the longest series of years can reasonably be rendered *available?* Let us first suppose that there is no pondage, and the natural flow only can be relied on. A glance at the diagram of average monthly flows on the Croton basin (No. 15), shows that for every month in the year 45.5 cubic feet per square mile per minute can be used,

the available flow being restricted to the least monthly flow. The same diagram shows, however, that a much greater flow is avaliable for nine or ten months continuously, and the owner might with advantage, if necessary, cease to employ water-power for one or two months in the year, and use the greater water-power for the remaining nine or ten months. He might, according to the diagram, secure continuously for ten months 1.4 times the power that would be available continuously for the whole twelve months. It would seem reasonable, especially when auxiliary steam-power is employed, that the highest rate of flow should be selected which can be secured for nine or ten months. Where it is a question only of the ability of the property owner to utilize the amount of water thus indicated, it is to be understood that he may introduce as many motors as he pleases, some of large power and others of smaller power, in order to employ the water to the best advantage; and that, especially with auxiliary steam-power, he may take advantage of the flow of water as it comes to him, under average conditions.

Nevertheless, it will be urged by some engineers that these average conditions do not show the exact monthly variations for different years; and that it is difficult, if not impracticable, to adapt hydraulic motors to the variations of flow, especially as these averages embrace the flood volumes, which are irregular, sudden, and often excessive. This is doubtless correct as far as ordinary custom in the utilization of water-power is concerned; and some writers have endeavored to correct the average flow by throwing out the flood volumes; a legitimate practice where the flood volumes are distinctly marked, and where they are of periodical occurrence, and can be separated from the ordinary flow; and such practice would generally be acceptable if the proportion of flood volumes to be rejected is established by common consent, and made a uniform practice. But mere guesswork—an arbitrary reduction of flow for which no scientific or rational reason can be given, does not, it seems to me, meet the demands of justice.

Where the public forcibly takes away a man's property, enlightened communities should favor, it seems to me, the most liberal estimates on which compensation is to be based rather than estimates which are founded on the arbitrary assumptions of individuals, over-zealous perhaps in their desires to serve the public. In this matter of available flow without pondage, therefore, the

highest average flow that can be realized for at least nine or ten months, leaving out the flow for the lowest summer months, in the absence of any accepted rule for rejecting extraordinary floods, seems a fair basis for estimating the available power for which compensation is to be made.

We come now to the consideration of the effect of pondage on this available flow. Natural storage reservoirs, even where the outlets are in no way under control, often have the most remarkable effect, as is well known, of equalizing the monthly flow; and thus increasing the amount of water that may be rendered available. Artificial storage reservoirs furnish the further very important advantage, that the delivery of the impounded water can be placed entirely under the control of the user. For example, in the supply of water to a town from a given stream under circumstances which render a storage reservoir necessary, the draught of water is continuous and nearly uniform for every day in the year, while the supply to the stream is variable; the greatest deficiencies occurring in the northern and eastern parts of our country, during the summer months. These deficiencies are made up, and the uniform draught made possible, by a large reservoir under control.

In the case of water-power, even where the power is used every day for twenty-four hours a day, a large reservoir may store up the water of floods to some extent, rendering a greater amount available; while in case the power is used only ten or twelve hours a day, a small reservoir capable of storing little more than the night flow, may practically double, for a large part of the year, the amount of water that could otherwise be used.

The quantity of water which may be stored in a given reservoir is a determinate problem; it is more difficult to estimate the effect of a given amount of storage in increasing the available supply, but the problem being to a great degree a mathematical one, there should be no reason for experts to differ materially in these calculations. What is needed is a method of demonstration which may be easily comprehended by jurors and others who are called upon to consider expert evidence; for there is little to be gained from the mere opinions of expert witnesses if their opinions are unsupported by evidence.

Storage has in most cases of riparian rights, such as we are considering, a most important and often preponderating bearing upon the points at issue; and that its influence should be well under-

stood, and capable of simple exposition, is of the first importance. By making use of a graphical mode of presentation, these desirable objects may I think be accomplished. Diagrams 15 and 16 will serve to illustrate this method. I am not aware that it has been before proposed, but am quite sure from my own experience that it will be found useful.

On diagram 15 the line-shaded area below the line which represents a flow of 91.4 cubic feet per square mile per minute, shows what storage is required in order to secure this flow for every month of the year. This area according to the scale represents 3,467,059 cubic feet for one square mile or about 3 per cent. of the whole rainfall, as represented on the same diagram. This will be recognized at once as a very small amount of storage. It arises from the fact that the flow of the stream is represented by monthly averages for a long term of years.

Diagram 16, on the other hand, shows that for the same available flow of 91.4 cubic feet per square mile per minute, a storage of 13,132,800 per square mile is necessary—nearly four times as much. But in this diagram we have the flow of a stream in the same water-shed, the Croton, for three years, 1869, 1870, 1871—very exceptional years—one of which was among the driest years of this century, while for the others the rainfall was irregularly distributed. This is evident from the diagram itself, in which the months are arranged not in chronological order, but in the order of the least to the greatest monthly flow, and which shows a a greatly deficient flow for the summer months, and excessive flow for the winter months. The last diagram would be, for practical reasons, the best to be selected for determining the storage necessary for the supply of 91.4 cubic feet per minute per square mile to a town, but its adoption for the determination of the rights of an owner of water-power would be in the highest degree unjust and ruinous to him. It is not to be questioned, it seems to me, that such an arbitrary and unfair selection of the conditions of available flow for a riparian owner should be ruled out, as discriminating improperly and unfairly against him.

If it be desirable to introduce losses by evaporation and leakage from the storage reservoir, these may be entered upon the diagram in cubic feet per square mile per minute for each month, making a broken line for the year, which represents the monthly consumption by actual draught, evaporation, and leakage, and the

vacant spaces below the line will not only show the amount of storage necessary, but the exact months when it must be drawn off. The especial value of the graphical method for such questions as we have under discussion is, that it shows at a glance and without special demonstration the effect of such storage in increasing the available flow.

Having determined the available flow, the available power of a stream can be determined. In the best turbine wheels, having an efficacy of 80 per cent., an amount of water equivalent to 660 cubic feet in a minute falling one foot will give a horse-power. The available fall in feet and the number of square miles of water-shed being known, the total power in horse-power can be readily determined.

The final question is, what is the intrinsic value of one horse-power in water-power? It should be assumed, I think, that when a part of the water-power of a stream is taken away, the cost to the owner of replacing that power with steam-power should be allowed.

There is no other source of power that can be relied on to replace water-power. This being admitted, it only remains to ascertain the yearly cost to the owner of his water-power, and the yearly cost of the substituted steam-power; the difference will represent the cost of substituting steam.

If we suppose, for example, the cost of a horse-power in water-power, to the owner, including the interest on the capital invested to utilize the water-power, to be ten dollars per annum per horse-power, and the cost of steam-power for twelve hours a day for the same period to be sixty dollars per annum, the cost of substituting steam will be fifty dollars per horse-power for twelve hours a day, or one hundred dollars a horse-power if the power is used twenty-four hours a day. It is quite evident from this as well as from general considerations, that the less the yearly cost of the water-power to the owner, the greater is its intrinsic value to him.

If the whole of the water-power of a stream is taken away the same principles should apply; for that which is applicable to any and every part is certainly applicable to the whole.

The claims on behalf of the riparian owner which I have endeavored to establish are, it seems to me, based upon truth and common sense, and yet experts are found every day who assume their own conditions arbitrarily, and thus decide in advance questions of right and justice, or of law, in such a way as to produce undue pre-

judice in the very beginning, against those who are obliged to appeal to the law for relief or redress.

Among the questions of law thus often assumed there are several which are of frequent occurrence, in regard to which there is no doubt that the popular sense of justice is against the assumptions, as being unfair and opposed to common rights. One of these is that a private owner is entitled to no relief or compensation unless he is, at the time his water privilege is impaired or taken from him, actually using it; or, in other words, that an unused or unimproved water-power is valueless as far as any compensation is concerned.

A riparian owner, for instance, may have a hundred horse-power available at small cost, which he may establish at his discretion, but if he has not such power actually improved and utilized he is entitled to no consideration in a claim for compensation. Or where an owner has only partially utilized the power at his disposal his claims are limited to injury to such partially-utilized power.

Another is, that, where land is taken for public purposes upon which there is such unused power, the enhanced value which the existence of the facilities for water-power gives to the land, over all other considerations, cannot be made the basis of any special claim for compensation. Such assumptions appear to be fundamentally wrong.

These particular questions do not belong to the engineer, perhaps, but he is often obliged to assume that they will be decided in favor of the owner, otherwise his labors and investigations may bring upon the latter useless expense.

THE KJELDAHL PROCESS FOR THE DETERMINATION OF NITROGEN.

BY E. WALLER AND H. C. BOWEN.

THIS process was devised by Kjeldahl, of Copenhagen, for use in connection with the brewing industry. The details were first published in 1883.*

* Fresenius, Zeit. Anal. Chem., xxii., 366.

A convenient amount of the nitrogenous material (0.5 to 1 gm.) was heated in a flask with 10 c.c. concentrated sulphuric acid with addition of Nordhausen acid, or phosphoric anhydride, until the solution was nearly colorless. Pulverized potassium permanganate was then cautiously added (to complete the destruction of the organic matter), until the green color of manganic acid appeared. After cooling and diluting, an excess of caustic soda solution was added, and on distilling, the nitrogen (now in the form of ammonia) was titrated in the distillate. The acid was caused to act upon the material at a temperature just short of boiling. To prevent the otherwise inevitable bumping on distilling with the soda, a few pieces of metallic zinc were added to the retort or distilling flask.

Kjeldahl found that the process, as described, failed to give all of the nitrogen as ammonia in some compounds of the fatty and aromatic series, in some alkaloids, and in nitrates, though as regards the latter, when sugar was added, a much larger proportion (60 to 80 per cent.) of the nitrogen than was expected was found to be converted into ammonia.

The theory of the process is given by Dafert as follows:

1. The acid withdraws from the material the elements of water.

2. The action of the acid upon the organic substance also affords SO_2, which acts reducing upon the nitrogenous material.

3. Where some nitrogenous compounds partially resist this action, the permanganate added toward the close of the acid treatment breaks them up, forming ammonia.

Treatment with Acid.

The relative proportions of concentrated sulphuric acid, Nordhausen and phosphoric anhydride, are not specified in the original paper. The proportion of Nordhausen acid used by different experimenters is from 20 to 50 per cent. Some, as Pflüger and Bohland, Kulisch, etc., use no phosphoric anhydride. Wilfarth also regards it as unnecessary when metallic oxides are used. It is noted by Kreusler and others that Nordhausen acid frequently contains nitric acid, which may consequently give untrustworthy results.

The proportion of phosphoric anhydride used is from 10 to 25 per cent. Some (as Kreusler) use phosphoric anhydride and omit the use of Nordhausen altogether, in some cases, however, using

in its stead the metallic oxides recommended by Wilfarth. Wilfarth's modification consists in the addition of about 0.1 to 0.6 gm. CuO, and 0.7 gm. HgO.

This recommendation has been further modified by the suggestion to use the anhydrous sulphates of those metals, or even metallic mercury in place of the oxide. HgO, prepared by heating the nitrate, is inadmissible in any case.

Kulisch, in experimenting on wines, found the addition of CuO to afford but little advantage in point of speed, which was one of the main points claimed by Wilfarth.

Schmitz applied Wilfarth's method successfully in the analysis of coal and coke.

Ulsch found that the operation was hastened by the addition of 5 drops of a $PtCl_4$ solution containing 0.04 gm. metallic Pt per c.c. Platinum black was unsatisfactory. Adding also 0.05 gm. CuO gave still better results. He found, however, that an excess of platinic chloride might easily cause loss of nitrogen.

Adding the acid by instalments was found to be of advantage in certain researches of C. Arnold, and of Brunemann and Seyfert. About one-fourth of the whole amount of acid was first added, and the flask gently heated until frothing had materially diminished, when the remaining three-fourths were added, and the operation conducted as usual.

It is asserted by Lenz that the size of the flask in which the operation is conducted has a material influence upon the amount of acid and of time required for effecting the decomposition. This may be the cause of the wide disagreement of different experimenters on those points.

To avoid loss by spattering, some use long, slender-necked flasks, while many others use some perforated bulb stopper arrangement in the neck of the flask. Slanting the flask also is another device. Special forms of heaters, protecting the flasks by wire gauze, or using the naked flame, etc., are details which have been differently managed by different analysts.

Use of Permanganate.

Czeczetka proposes the use of a solution of the permanganate in concentrated sulphuric acid, instead of the pulverized form. Lenz, Kulisch and some others regard the use of this reagent as a

very necessary part of the operation, but C. Arnold, as well as several others, omit it as useless. With these latter, Asboth agrees only partly, stating that it is necessary in the case of difficultly decomposible substances, as morphine, etc. On the other hand, Wilfarth and some others regard its use as involving possible loss of ammonia. Many of the chemists referred to quote analyses in support of their views on this point.

Distillation.

Bumping is prevented by passing a current of steam through the solution, by Petri and Lehmann.

Asboth adds enough Rochelle salt to prevent any precipitation of metallic hydrates by the alkali. Wilfarth found that bumping occurred when soda was used, but not with potash. Scovell's experience is exactly the reverse. It is noted by many experimenters that the evolution of hydrogen when metallic zinc is added, causes some of the alkali to be carried into the distillate, and to obviate this, some advise interposing wire gauze, or glass beads, etc., in the neck of the distilling flask, while others use a bulbed tube above the flask. Much of the caustic soda and potash sold for laboratory use has been purified by fusion with nitrate, and in contact with zinc this may afford enough ammonia to interfere with the correctness of the results.

When mercury or its compounds have been used in the treatment with acid (Wilfarth's process), potassium or sodium sulphide must be added, to break up the mercur-ammonium compounds. Ulsch uses ferrous sulphate for that purpose.

Presence of Nitrates.

To *remove* nitrates when present, Warrington first heats the material with ferrous sulphate and hydrochloric acid, and, after drying, proceeds as usual. Reitmair accomplishes this by heating the substance with sulphuric acid in a tin capsule, finally throwing capsule and contents into the decomposition flask. The French Association of Sugar Chemists remove the nitrates by heating for some time at 110° C. in contact with oxalic acid.

To *determine* the nitrogen in nitrates by this method, Asboth proposes the addition of about 1 7 gms. benzoic acid to every 0.5 of nitrate. Spencer and C. Arnold, however, did not obtain satis-

factory results by this means, though the latter found it fairly good when larger amounts of benzoic acid were used. Jodblauer proposed the use of phenol sulphuric acid, followed by zinc dust, the theory being that nitrophenol is at first formed, which by the action of the zinc is converted to an amide, and by the subsequent treatment into ammonia. Stutzer and Reitmair only find this method effective after treating the material with water, and evaporating to dryness in order to distribute the nitrate through the mass in a finely divided condition. Salicylic acid, instead of phenol, has been found by Scovell to be more advantageous. He prescribes for 0.7 to 1.4 gms. of the substance, 30 c.c. sulphuric acid and 2 gms. of salicylic acid, followed by the gradual addition of 8 gms. of Zn dust, and then 2 or 3 drops of platinic chloride. After gentle heating until frothing ceases, and then more strongly for five or ten minutes, 0.7 gm. HgO is added, and the heating continued as usual.

General.

The process commends itself in the examination of many nitrogenous substances, on the score of expense of material and of trouble; in the matter of economy of time, the statements are very diverse. It seems hardly safe as yet to claim for the process universal applicability. It has been noted, especially with azo and diazo compounds, that the treatment permits of some loss of nitrogen in the elemental state, and with some others, as those of the pyridin and chinolin group, the process seems to fail.

In using this process upon fertilizers, flour, cattle foods, and material of that nature, we have found that many of the devices recommended by other experimenters can be made unnecessary. A method found to be satisfactory is as follows:

The substance to be examined is first tested as regards its action with concentrated sulphuric acid. Then 0.5 to 1.5 gms. of the material is weighed out in a flask of 100 to 150 c.c. capacity: the flask should have preferably a short wide neck (nearly one inch diameter). Enough concentrated sulphuric acid (usually 5 to 12 c.c.) is then added, to maintain a liquid state of the mixture on heating. If too little acid is used, a coke-like mass results, which is difficult to manage. After adding the acid, a short funnel with wide stem may be inserted in the neck. Such funnels may be easily made from glass tubing of about ⅜ inch internal calibre.

The heat is applied gently until foaming ceases, when it is gradually increased. The heating is performed on a tin plate, with or without a bit of sheet asbestos under the flask. When the condition of the contents of the flask will permit it (which is usually very soon after frothing has ceased), a clay chimney is placed about the flask, to protect it from the cooling influence of the external air. *The mouth of the flask and funnel must be below the top of the protecting chimney or guard.* It may even be well to lay a clock glass across the top of the guard, leaving of course some exit for the fumes. The flame of a good Bunsen burner may be applied, to the extent of heating the supporting plate to a cherry-red. Thus arranged, the oxidation and simultaneous evaporation of the sulphuric acid proceeds very rapidly. The heating is kept up until the contents of the flask are reduced to about 2 c.c. Under the conditions described this will take about an hour. Ordinarily the solution is then quite colorless, at times it has a pale reddish tint, and sometimes, though rarely, the reddish tint is deeper. In the latter case 2 to 3 c.c. of Nordhausen acid are added, and it is heated as before.

After obtaining a solution which is nearly or quite colorless, the contents of the flask are allowed to cool before adding the permanganate (in powder). After adding this reagent, gentle warming will cause it to exert its effect. Now evaporate down to about 1.5 c.c., cool, dilute with water to about 150 c.c. and transfer to an Erlenmeyer flask of about 250 c.c. capacity, having a doubly perforated stopper. Through one hole passes a bulbed exit tube leading to the condenser, through the other a stop-cock funnel tube, the end of which reaches nearly to the bottom of the flask. Through the latter a solution of caustic soda or potash is introduced, in sufficient quantity to give a decided precipitate of manganous hydrate. The distillation can then be effected without difficulty. The end of the condenser is allowed to dip into water containing a known amount of standard acid, which is titrated back as usual, after distilling off about one-half of the contents of the flask.

The principal advantages of this mode of management consist in a marked saving of time, and increased effectiveness of the sulphuric acid, thus dispensing for ordinary work, with any addition of phosphoric anhydride, metallic oxides, etc. Moreover, by driving off much of the excess of acid, and exercising reasonable care in the

neutralization of the remainder, the distillation can be effected without danger from the bumping of the solution.

We have not investigated as to how far it may be possible to omit altogether the use of the permanganate, though it seems probable that in many cases it might be dispensed with.

In the table below are some of the results obtained, as compared with the Ruffle and absolute methods. The results on sodic nitrate and fertilizers containing nitrate are only given as confirmatory of the failure of the method to give trustworthy results without modification. With pure nitrate a considerable quantity of sugar was used. The Ruffle method also fails in presence of nitrates.

	Kjeldahl.	Ruffle.	Absolute.	Theory.
Urea, ...	46.662	.....	.....	46.754
"	46.620	.....	.....	46.754
"	46.816	.....	.....	46.754
"	46.704	.....	.....	46.754
Impure ammonia sulphate,	20.42	20.70	.....	21.21
Sodic nitrate, . . .	4.49	11.64	16.6	16.47
Cotton-seed meal, . .	6.20	6.30	6.37	
" hulls, . .	0.448	.....	.....	
Fertilizer	2.72	2.42	2.74	
"	2.26	2.33	2.25	
" containing nitrate,	1.18	2.00	2.40	
" "	1.93	2.36	2.44	
" "	3.44	4.06	4.51	

It may also be added that the students in the Quantitative Laboratory of the School of Mines have repeatedly obtained, by the Kjeldahl process, results on fertilizers which agree closely with those obtained by the more elaborate combustion processes.

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SOME NOTES ON BRIDGE STEEL.

BY R. W. HILDRETH.

AT the present day a large percentage of the bridges built, are made either partly or entirely of steel, and the probability is, that the near future will see this material used exclusively.

There are, however, nearly as many different specifications, as there are bridges built for different parties. In some a uniform grade is specified for all parts, in others a higher steel is used for compression than for tension members. The ultimate strength is usually allowed to vary between limits from eight to ten thousand pounds apart, the lower being set at various points between 56,000 and 80,000 pounds per square inch.

Bridge manufacturers, however, almost universally prefer to use a low rather than a high grade, as such a steel is much easier for them to work, and is less liable to rejection on account of defects produced or developed during manufacture.

A soft steel is preferable to wrought iron for bridge purposes, because it gives the same or greater strength for less weight, it is less liable to injury in the shop, can be worked as easily, and costs about the same, or less. In other words, a better bridge can be built of soft steel than of wrought iron, for the same, or a less first cost. In the opinion of the writer, it is preferable to the harder grades of steel, for the following reasons:

1. It is more uniform in quality as furnished at present.

2. It is more easily worked, and is less liable to be over-heated or otherwise injured during the process of forging.

3. It is less brittle, and in consequence is less damaged by straightening or bending cold, punching, shearing, accidental shocks, or the repairing of work incorrectly made.

4. Flaws of all kinds are less injurious, and especially so in the forged parts of tension members, due largely to the greater welding properties of the soft steel.

5. The delays are less, because the rejections are less. It is usually from three to four weeks after material is ordered, before it is received at the shop. Bridges can frequently be erected only at certain seasons, and a delay of three weeks is a serious matter.

6. A greater unit strain is not justifiable in the higher steel, particularly in tension, because in two or three parts of the structure there may be flaws or other defects, that will render their strength less than if made of the milder grade; also because the harder steel is relatively less capable of withstanding shocks.

The results of a few tests of steel of different grades are given in this article. They, together with many others of no special interest, from which they were selected, were made in the ordinary course of testing material for existing bridges, and were not specially prepared tests.

Table I. gives the results of some tests of a rather high grade of steel, and shows the effects, in full size eye-bars, of small flaws and other defects developed in the steel subsequent to its rolling. All the tests in each set are from the same melt. The small size tests of A, B, C, D, and E show that the quality of the steel is such as would be accepted under any specifications, requiring the grade to which this steel belongs. Yet in each case the results of the full size tests are bad. That the cause of these bad results, was some special local defect in each bar, was demonstrated by re-heading, re-annealing and re-testing all of these bars, with good results in every case. The second tests are not given, as they were made for another purpose, and the set to which each belonged was not noted. B, 5 gave a good result, while those of the other two bars from the same melt were decidedly bad. The record of the blow number of D was lost, so the results of the small size tests are not known, except that the ultimate was over 67,000 pounds per square inch, the elongation over 20 per cent. in eight inches, and the reduction of area over 42 per cent. The small size tests of F and G were not noted; the ultimate was, however, over 70,000 pounds per square inch, the elongation over 20 per cent. in eight inches, and the reduction of area over 42 per cent.

The set H, is given as an example, showing correspondence of results in full size to those of small size tests, and is but one of many similar, that could be given.

Tests I and J show that cold straightening frequently determines the point of fracture. The points where these bars were bent, were marked with paint, before they were straightened; the fractures took place at these points and were granular at the edges, gradually changing to silky at the centre. This appearance was to be expected, as the fibres near the edges would be the most distorted

TABLE I.

No. of Test.	Specimen.	Size.	Elastic Limit per sq. in.	Ultimate Strength per sq. in.	Elongation. Taken in.	Elongation. Per cent.	Red. of Area. Per cent.	C. Per cent.	Mn. Per cent.	P. Per cent.	Remarks.
A 1	Bessemer steel, ¾"O	".752 dmt.	43570	71380	8 in.	27.3	52.4	0.18	0.61	0.061	Silky cup.
A 2	Cut from 7" x 1¾" bar	".798 dmt.	40000	68190	8 in.	23.0	46.3	...	...	...	Silky cup.
A 3	Full size bar, 7" x 1¾"	7".09 x 1".71	38700	47120	22ft.	2.2	...	...	...	...	Square, coarse, crystalline fracture in head, in small flaw. Fl'w was chipp'd before testing, but was not removed entirely.
A 4	Cut from head of No. 3, next to fracture. Hammered to ⅞"O, but not annealed.	...	47740	75720	8 in.	13.8	39.7	...	...	...	Silky.
B 1	Bessemer steel, ¾"O	".750 dmt.	41530	67460	8 in.	28.3	53.0	0.17	0.53	0.074	Silky.
B 2	Cut from 7" x 2" bar	".825 dmt.	39840	66780	8 in.	26.3	45.0	...	...	...	Silky.
B 3	Full size 7" x 2" bar	6".95 x 1".88	33130	44900	22ft.	4.3	8.1	...	...	...	Square, coarse, crystalline fracture in neck. Cause unknown.
B 4	Full size 7" x 2" bar	7".10 x 2".00	36630	57020	22ft.	6.0	...	...	...	...	Square, coarse, crystalline fracture in head. Cause unknown.
B 5	Full size 7" x 1⅞" bar	7".08 x 1".86	37480	66280	21ft.	21.9	52.5	...	...	...	Silky cupped fracture in body.
B 6	Cut from head of No. 4, next to fracture. Hammered to ⅞"O, but not annealed	...	42980	67360	8 in.	21.5	55.2	...	...	...	Silky.
C 1	Bessemer steel, ¾"O	".750 dmt.	41880	70170	8 in.	24.0	53.8	0.18	0.68	0.072	Silky.
C 2	Cut from 7" x 1¾" bar	".817 dmt.	41970	70200	8 in.	27.5	48.4	...	...	...	Silky.
C 3	Full size, 7" x 1¾" bar	7".06 x 1".25	39080	52720	21ft.	3.4	4.3	...	...	...	Square, coarse, crystalline fracture in upset clamp marks.
D	Full size Bess. steel 5" x 1⅜"	5".06 x 1".36	36470	57810	28ft.	8.5	...	...	...	...	Square, coarse, crystalline fracture in head, in small flaw.
E 1	Bessemer steel, ¾"O	".755 dmt.	41210	67460	8 in	27.5	45.4	0.18	0.67	0.074	Silky.
E 2	Cut from 7" x 1⅜" bar	".816 dmt.	41300	68840	8 in.	25.8	51.2	...	...	...	Silky.
E 3	Full size, 7" x 1¾" bar	7".12 x 1".74	34900	47900	28ft.	4.2	...	...	...	...	Square, coarse, crystalline fracture in head. Cause unknown.
E 4	Cut from head of No. 3, next to fracture. Hammered to ⅞"O, not annealed.	...	38950	65090	8 in.	20.5	47.7	...	...	...	Silky.

TABLE I—*Continued.*

No. of Test.	Specimen.	Size.	Elastic Limit per sq. in.	Ultimate Strength per sq. in.	Elongation. Taken in.	Elongation. Per cent.	Red. of Area. Per cent.	C. Per cent.	Mn. Per cent.	P. Per cent.	Remarks.
F	Full size Open Hearth steel bar, 7" x 1½".	...	38840	46030	19ft.	2.5	...	...	...	...	Square, coarse, crystalline fracture in head. Cause unknown
G	Full size Open Hearth steel bar, 7" x 1¾".	...	34630	56080	20ft.	6.3	...	...	...	...	Square, coarse, crystalline fracture in head, in small flaw.
H 1	Bessemer steel, ¾"□	".758 dmt.	41000	71460	8 in.	25.0	49.3	0.14	0.71	0.067	Silky.
H 2	Cut from 7" x 2" bar	".810 dmt.	41530	70840	8 in.	22.5	50.5	...	...	...	Silky.
H 3	Full size 7" x 2⅛" bar	7".13x2."13	41620	70630	24ft.	13.5	41.5	...	...	...	40 per cent. silky at centre. 60 per cent. fine gran. edges.
I	Full size Bess. steel 5" x 1¼".	5".08x1".26	37290	60550	33ft.	12.3	47.2	...	...	...	Both bars bent in annealing straight'd cold. Fracture occur'd at bend. Silky centre, granular edges.
J	Full size Bess. steel 5" x 1¼".	5".08x1".26	38560	62140	33ft.	10.0	43.6	...	...	...	
K 1	Open Hearth steel, ¾"□	".755 dmt.	41880	68130	8 in.	30.0	55.3	0.19	0.66	0.076	Silky.
K 2	Cut from 4" x ¾" bar	".750x".740	41710	69550	8 in.	26.3	55.0	...	...	...	Silky.
K 3	Full size, 4" x ¾" bar	4".02x0".76	39450	46140	31ft.	2.1	4.3	...	...	...	Square, granular fracture, in upset clamp marks.
K 4	Cut from No. 3 next to fracture. Not annealed.	".781x".507	43180	63260	8 in.	22.0	58.6	...	...	...	Silky.
K 5		".755x".505	49050	65040	8 in.	21.8	51.4	...	...	...	Silky, elastic limit indefinite.
K 6	Full size, same bar as No. 3, but with new head and re-annealed.	4".00x0".75	42830	63910	28ft.	8.1	48.3	...	...	...	Silky cup centre, gran'r at edges. Before testing clamp marks caref'y remov'd by chipping and filing. Fracture not in clamp marks.
L	Full size Open Hearth steel bar, 4" x ¾".	3".96x0".77	40120	66200	31ft.	15.0	47.9	...	...	...	Silky at centre, gran'r at edges. Clamp marks chipped and filed out of these bars. Fracture not in clamp marks.
M	Full size Open Hearth steel bar, 4" x ¾".	3".96x0".76	42010	67760	31ft.	14.6	43.5	...	...	...	

by the straightening. Many bars give similar fractures when broken, and in every case the appearance is probably caused by previous cold straightening. In the above examples, the ultimate strength is probably from six to seven thousand pounds under what it would have been had the bars not been previously bent and straightened. Soft steel is much less injured by such treatment than the harder grades.

TABLE II.

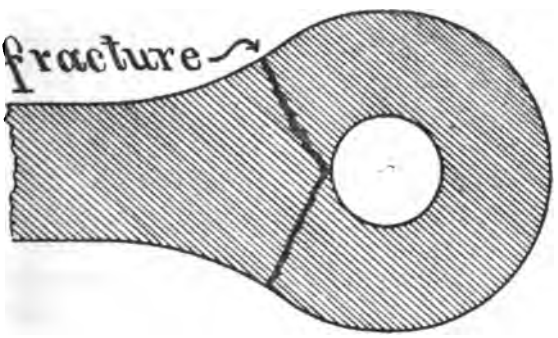
No. of Test.	Specimen Open Hearth Steel.	Size.	Elastic Limit per sq. in.	Ultimate Strength per sq. in.	Elongation. Taken in.	Elongation. Per cent.	Red. of Area. Per cent.	Remarks.
A 1	Cut from 5″ x 1″ bar.....	″.490 x ″.995	36250	72660	8 in.	15.0	14.6	Granular burnt.
A 2	Full size, 5″ x 1″ bar.....	5″.05 x 1″.00	34730	64620	13ft	12.2	33.3	Fracture 75 per cent. fine granular at edges, 20 per cent. silky at centre. Broke in body.
B 1	Cut from 6″ x 1″ bar.....	1″.024x″.498	34080	64260	8 in.	20.2	29.2	Silky.
B 2	Cut from 5″ x 1″ bar.....	1″.004x″.494	31190	57000	8 in.	24.4	39.2	Silky.
B 3	Full size, 6″ x 1″ bar.....	5″.97 x 1″.02	32490	58610	17ft.	15.7	44.9	Fracture silky at centre, granular at edges. Broke in body.
B 4	Full size, 5″ x 1″ bar.....	5″.03 x 1″.00	32440	57980	8 ft.	20.9	46.8	Silky cupped, broke in body
C 1	Cut from 5″ x 1″ bar.....	″.971 x ″.493	33010	60480	8 in.	24.1	36.9	Silky.
C 2	Full size, 5″ x 1″ bar.....	5″.04 x 0″.97	35050	57190	12ft.	20.4	48.1	Silky. Broke in body.
D 1	Cut from 5″ x 1″ bar.....	″.985 x ″.498	31850	57840	8 in.	22.8	39.9	Silky.
D 2	Cut from 6″ x 1″ bar.....	″.996 x ″.497	29210	57150	8 in.	26.5	41.8	Silky.
D 3	Full size, 5″ x 1″ bar.....	5″.02 x 1″.00	34120	54440	11ft.	20.6	42.4	Silky cup. Broke in body
D 4	Full size, 6″ x 1″ bar.....	5″.98 x 1″.00	30695	54230	8 ft.	22.9	40.2	Silky centre, fine granular at edges. Fine cracks at back of one head, these opened up, but bar broke in body.

In the set K, a series of tests are given which show conclusively, that the bad result of No. 3 was entirely due to the marks left by the clamps of the upsetting machine; for, after these marks were removed by chipping and filing, this same bar gave excellent results, the elongation being as good as could be expected, considering the bar had been previously stretched permanently more than four per cent. of its length. Similar results were obtained with other bars, but the one was deemed sufficient for illustration. In tests L and M the clamp marks were removed in the first place before testing and the results were good, the fracture not taking place at the points where the clamp marks had been chipped out.

One peculiarity was noticed in these bars; the points that had previously been depressions made by the teeth of the clamps, became after testing, elevations, in the shape of a series of ridges. This indicated that the marks, not only served as a starting point for the fracture, but that the pressure had hardened the material at these points.

In Table II., a few tests are given of a very soft grade of steel. The only ones of any special interest, are those of set D. The full size bar, that gave the result D 4, had a few cracks on the edge and at the back of one eye; these cracks were perpendicular to the face, from one quarter to a half inch deep, and extended through the full thickness of the head. On testing, the bar broke in the body, with excellent results, the cracks in the head simply opening up, the deepest about one-sixteenth of an inch. The writer has tested many bars with similar flaws in the heads, and where the steel was over 62,000 to 64,000 pounds in the ultimate strength, he has never known one that did not break in the flaw. When a bar does break in such a flaw the ultimate strength is always very low, and the elongation only from two to six per cent.

That high steel will break suddenly in any crack, nick, or other defect, is well known. The softest steels, however, lack this



property almost entirely, where they have not been overheated or otherwise rendered brittle; and this alone is a very strong argument in favor of their use for structural purposes.

It may be noted here, that every cause operating to make soft steel brittle renders hard steel much more so, and that these causes occur more frequently and easily with the latter than with the former.

The illustration shows a case, where the fracture occurred in a

bar at the point of greatest section, simply because a small flaw was the starting point.

In compression members, high steel gives a great deal of trouble during the processes of manufacture. In straightening plates by blows of sledges (the customary method), they will frequently crack so as to be rendered useless for their purpose. In shearing, the material will occasionally break, back of the line of shear, with a resulting loss of the piece. In punching, the variability in quality of high steel is very apparent; at some points the metal will give gradually under the punch, while at others in the same plate or angle, it will break away with quite a sharp report. At points where the material is most brittle it not infrequently happens, that cracks will form from the rivet holes to the nearest edge.

Where work is incorrectly made in the first place, portions of it are sometimes rendered worthless, by cutting out rivets in the endeavor to correct the error. This is so frequently the case, that, for unimportant errors, it is often better to accept work, rather than run the risk of having it spoiled entirely, and submit to the necessary delay required to replace it.

On one bridge, the writer knows of three cases, where the two angles riveted to the side plates of compression members were broken off short, each fracture occurring while handling the piece in the shop. In two cases, while hoisting both ends of the finished piece at the same time, the chain at one end broke, dropping that end four or five inches. In one of these cases both angles were broken by the shock, in the other, the whole side was bent a little, and the angles were broken in trying to straighten it with a jack. In the third case, the plate was bolted to the two angles ready for riveting, and was being hoisted by one chain at the middle; a kink in the chain simply straightened out, dropping the piece about two inches, but the shock was sufficient, added to the strain from the weight of the piece itself, to snap both angles off short at the centre. These angles, which were 4″ x 4″ x ¾″ were obtained under specifications which placed the lower limit of the ultimate strength at 65,000 pounds, set no upper limit, and placed the reduction of area and elongation so low that steel up to 75,000 pounds ultimate could pass them easily.

Two small size specimens were tested from one of these broken angles (the third case), one was cut from the fractured end, and the other as far from the first as possible. The results are given in

TABLE III.

No. of Test.	Specimen.	Size.	Elastic Limit per sq. in.	Ultimate Strength per sq. in.	Elongation.		Red. of Area. Per cent.	Remarks.
					Taken in.	Per cent.		
1	Cut from 4″ x 4″ x ¾″ angle	″.750 x ′.505	37230	65490	8 in.	26.0	50.4	Cut from angle next to fracture. Silky.
2	Cut from 4″ x 4″ x ¾″ angle	″.764 x ″.509	38320	65310	8 in.	25.3	54.1	Cut from end of angle not broken. Silky.

Table III., and show a good quality of material. The elongations and reductions of area indicate that the steel was of good average ductility for its ultimate strength, and had not been burned, overheated, or otherwise injured: it would be accepted under any specifications for that grade.

Some soft steel angles 5″ x 3½″ x ½″, from the same melts as the tests of Table II., were tested in various ways. First they were flattened out cold under a hydraulic press, then nicked all around and hammered back and forth, in each case two or three times before breaking, and even then they would tear apart, and not break suddenly as hard steel would do if similarly tested. These angles were then submitted to a punching test, in which a series of $\frac{1}{16}$″ holes were punched to within an eighth of an inch of each other and of sheared edges, without a single crack forming. When a hole was punched within $\frac{1}{16}$″ of an edge, the thin wall of metal would be carried along with the punch, but the hole would not crack out even then.

Such a test is one that the best wrought iron could not stand. Contrast these results with the ordinary working of iron or hard steel in the shop, in which it is not uncommon for cracks to form through an inch and a half of metal, in punching.

In conclusion, the writer would say, that in his belief, a bridge made of steel from 56,000 to 64,000 pounds per square inch in ultimate strength, and with a corresponding ductility, is a safer structure than a similar one built of any grade above 65,000 pounds.

THE EXTRACTION OF COPPER AT AGORDO.

BY PROF. T. EGLESTON, PH.D.

(Continued from page 139.)

3. LEACHING THE ROASTED ORES.

THE ores are leached in a series of 64 wooden vats, 3.50 m. square and 1 m. deep, placed in steps of four each. The leaching is done cold. The top of each vat is on a level with the bottom of the one above it. They are always 3 m., at the least, wide and 1½ m. high. Thirteen tons of ore to be leached are placed in the lowest one every day, and allowed to remain there twenty-four hours. It is then removed to the second, and so on. The ore thus goes up the series, remaining twenty-four hours in each vat. Nine cubic metres of water are placed in the upper vat which comes down, remaining no longer than twenty-four hours in each vat. About 8 cubic metres of solution at about 30° B. are drawn from the lower vat every morning. Washing in this way, the water in the lowest one, which is already charged with some sulphate, comes in contact with the ores richest in sulphates. The fresh water comes in contact with those ores from which the sulphate has been almost entirely dissolved. The charge of each vat is made with wheelbarrows in the morning. Those in the highest one are considered as treated, and are taken out to a large drainage area, provided with drainage ditches, on which they are drained and dried. They are so acid that the wheelbarrows used to transport them are soon destroyed. The charge in No. 1 is about 13 tons of fresh ore. When the areometer marks 30° to 34° B. for the rich, and 14° to 15° for the poor waters, or an average for the mixture of 26° to 27° B., the water is drawn off into reservoirs, where they wait their turn for concentration, and the water in the next higher one is let into the lowest one, and so on, and fresh water is added in the highest. The ores which have been washed still contain copper, because in roasting a part of the sulphate has been transformed into oxide. The residues are therefore always used for covering over the piles of ore, for the sulphuric acid which is given off transforms the larger part of the oxides into sulphates.

The residues so treated are always poorer than the roasted ores, and for that reason they are always treated separately. After the second lixiviation, which yields almost as much as the first, the earth is made to pass through sieves having holes 0.01 m. to 0.015 m. in diameter. All that passes the sieves, as it contains only from 0.25 to 0.50 per cent. of copper, is thrown away as sufficiently treated. What remains, which is about half, is re-roasted on the bottom of the pile, and lixiviated a third time. To prevent the oxidation of the iron and precipitation of the hydrated sesquioxide of iron, the surface of the liquors is covered with sawdust or with planks. The third lixiviation yields but very little, for the areometer stands in the lowest one only at 13° to 14° B. The largest quantity of the water is as high as 30° B. Some small quantity only is as low as 13°. The loss of copper is estimated at from 8 to 10 per cent. The cost of the lixiviation is between $0.33 and $0.35 per ton of ore treated. This includes almost the total expenses, for as the water is brought in launders the workmen have no trouble to get it. The treatment would be much more efficient if the water, instead of flowing down by gravity, was pumped up, and the ores allowed to remain in each of the vats until they were leached out. This would make it necessary to invert the movement of both ore and water, but would result in much better work being done with much less labor to do it. In order to avoid the loss of time resulting from discharging the tubs, they might be suspended on trucks running on a railway, so that they might be elevated to the proper position without discharging the ore until it has been completely lixiviated, as is frequently done in soda manufactories, and the spent ore might be sluiced out instead of being discharged by hand.

The amount of material extracted by lixiviation from the ores is small. That remaining in the leached residues is an oxide of iron, which contains considerable sulphur. The amount of iron required by the works to precipitate the copper is about 300 tons a year. If the leached material was used in a blast furnace for the manufacture of pig, it might be so carefully roasted as to drive out a large amount and so reduce the amount in the pig as probably to justify the sale of any surplus. The sulphur in the pig required for precipitation would do no harm. The cost of manufacturing the pig would be very much less than its market cost, and would, besides, do away with the large amount of freightage.

4. Precipitation of the Copper.

For a long time the waters which were treated by cementation were separated into two categories, rich and poor. The rich were treated hot, and the poor cold. It was then found best to unite them and treat them both together. This treatment was effected in two different ways, owing to the fact of the separation of the liquors. Use was made of the old tanks, which were formerly used for the treatment cold, as long as they lasted. They were made 4 metres long, 3 wide and 1.50 deep; they were altered to suit the new circumstances, but they do not answer so well, nor are they so economical as the furnaces built for that purpose. The apparatus adopted for treating the hot liquid is a reverberatory furnace, solidly built; the hearth is made of blocks of limestone joined with hydraulic cement. The sides are made of talcose schist reinforced with iron bars and covered with hydraulic cement. The furnace has a capacity of 17 cubic metres. The hearth of the furnace is rectangular in shape, 1.0 metre deep, 3.50 metres wide and 12 metres long. The fireplace is 2 metres wide by 50 centimetres long, and the fire bridge 0.75 metres long, and is 20 centimetres from the top of the roof. The flue is 30 centimetres square and leads to a chimney of the same size. The old apparatus for the treatment cold were large tanks of wood lined with lead, holding 21 cubic metres. In order to utilize these cast-iron cylinders have been set into them, which are covered with a cap leading through the tank. These are coated with lead to prevent the action of the liquors on it. They are heated with wood and peat. The smoke is carried off by a pipe which passes through the side of the tank. When the furnace has been cleaned, two benches of wood are placed on the bottom and a ton of cast-iron or of scrap-iron placed upon them. The cast-iron is broken so that each piece will have at least 4 square centimetres of surface; 15 cubic metres of water containing copper sulphate are then introduced, which are made up of 12½ of rich and 2½ of poor, there being but little variation in the amount of liquid introduced. The temperature is gradually raised to about 60° C., and is kept between 60° and 70°, or, on an average, 65° C. The action of the iron is very rapid; in less than 12 hours the sesquioxide of iron is first reduced to protoxide, and then all the copper is precipitated. The precipitation of the copper does not take place until after the reduction

of the sesquioxide is complete. When the copper is all precipitated, the water is dirty yellow. The composition of the cement before and after treatment with iron is given below :*

	Before.	After.
Copper oxide,	1.38	0.06
Protoxide of iron,	6.91	8.72
Oxide of zinc,	1.78	2.32
Alumina,	0.66	0.74
Arsenious acid,	0.24	
Free sulphuric acid,	2.08	0.65
Combined sulphuric acid,	12.61	14.15
Water,	73.68	72.48
	99.34	99.12

It is easy to see whether there is any copper remaining in the liquid by testing the water with a piece of polished iron. When the copper is all down, which takes about 12 hours, the furnace is closed and the liquid left to settle. It generally requires 18 hours to settle it entirely, and it is generally left 24 hours, only 48 are required for the whole operation. When settled it is decanted with a siphon and made to flow into vats, where the iron sulphate is crystallized. The lower part of the water is rily. This is conducted into other vats to settle. The residue is metallic copper, subsulphate of iron, containing about 10 per cent. of copper, and some insoluble compounds of arsenic and iron, and the carbon of the cast-iron. This material is very impure. When the water is all drawn out, fresh water is introduced into the laboratory of the furnace, and it is washed with a heavy broom very carefully. This washing water is run into receivers, where the copper is settled from it. In the furnace sufficient iron is now added to make up the ton, and a new operation commenced. About 100 operations a year can be made in the reverberatory furnace. In the lead-lined vats the operation is conducted in the same way, but it is much slower, for the heat cannot be raised in the same time. Much more fuel and time are consequently used, and the operation costs more. While 100 operations can be effected in the reverberatory, only 82 can be made in the tanks. The results are the same as in the reverber-

* Annales des Mines, 7th Series, vol. ix., p. 199.

atory furnace; the cement copper contains 50 to 60 per cent. of copper.

Owing to the fact that the liquors remain a very long time in contact with the iron in the tanks, the arsenic contained in the liquor is precipitated as a subarsenide of sesquioxide of iron, and with it a considerable quantity of the hydrated sesquioxide of iron, so that the cement is not only rendered so poor in copper that it contains only from 50 to 60 per cent. of it, but it also rendered very impure. This occasions a loss of copper in refining equal to nearly 10 per cent. The amount of iron used is also necessarily increased. It is generally 4 of iron for 1 of cement copper. The cement is divided into two parts. The very fine stuff which deposits from the rily water runs out of the tank near the bottom, and also that resulting from the washing of the tank. These are called *brunini* if they do not contain more than 10 per cent. of copper. The large pieces, which are generally from the bottom of the tanks, are called *grassure.*

Taking the statement for 1865, the

Amount of iron used was, ...		640,800
Iron required to precipitate the copper, .	195,610	
Iron dissolved in the basic salts, . . .	28,601	
Iron dissolved by free sulphuric acid, . .	72,226	296,437
Not accounted for, ...		344,363*

Up to the year 1874 the operations were all conducted in this way.† The amount of iron used was, however, very often as high as 3.20 to 3.30 or even 4 for every unit of copper precipitated. The sub-salts of peroxide of iron used were very voluminous, very impure, poor in copper, and the fact of their presence caused as much as one-seventh of all the waters to be thrown away without complete extraction of the copper they contained. It was discovered that the leach waters contained besides the copper sulphate a large quantity of sesquioxide of iron sulphate, and that these salts consumed the cast-iron used in precipitation to no purpose, so far as the throwing down of the copper was concerned, and that the copper precipitated

* Church's Metallurgical Journey in Europe, p. 17. N. Y. 1873.

† Annales des Mines, 7th Series, vol. ix., p. 191.

was redissolved while any of these salts remained. This is shown as follows:

$$Fe^2O^3 3SO^3 + Cu = 2(FeOSO^3) + CuOSO^3.$$

So long as there was no sesquioxide sulphate in the liquors, this, in the presence of the cast-iron, was reduced to subsulphate of sesquioxide, so that the presence of the sesquioxide sulphates was not only the cause of the large quantity of iron used, but also of the very impure sub-salts of iron. It was proposed to reduce these salts with sulphurous acid.

$$Fe^2O^3 3SO^3 + SO^2 = 2FeOSO^3 + 2SO^3.$$

When this has been effected and iron added to the liquor, the copper was precipitated without any of the impure sub-salts of iron being formed.

As there was a large quantity of sulphurous acid produced at the works, this was made use of by the construction of a reverberatory furnace of a special form. It has two fire-places in which the ore is burned to produce the sulphurous acid required for the reduction of the iron salts. These communicate with a hearth composed of a tank having a capacity of about 24 cubic meters. It is 6 m. long, 4 m. wide and 1 deep. A flue, 40 centimetres high and 1 m. long and wide, communicates with a chimney. In this chimney a series of 12 diaphragms, slightly inclined and reaching seven-eighths of the distance across it, are placed. These are equally spaced; the highest being 7.30 m. from the ground and the lowest 3.80 m., or just 1 m. above the bottom of the flue. The series of diaphragms is 4.60 m. in height. The water is pumped up to the level of the highest one and falls slowly over all of them in shallow and wide streams, and drops against the current of sulphurous acid coming up from the furnaces and collects in the tank of the furnace below. In this way, not only the surface of the water in the tank, but every particle of it, in flowing down the diaphragms comes into intimate contact with the gas. Seven tons of cast iron are placed on the bottom of the furnace. The waters to be treated are heated to 34° C. and are then slowly introduced into the furnace against the current of sul-

phurous acid coming up. At the commencement of the operation a considerable quantity of hydrogen is given off, which diminishes as the cast iron becomes coated with copper and is protected from the free sulphuric acid. The temperature is kept constant for three days. The fourth day it is heated to 38° C. On the fifth day it is raised to 40° C. and 500 kilos of fresh cast-iron added to hasten the precipitation of the remaining copper. The waters are then allowed to settle for 24 hours, and at the end of the sixth day they are decanted. The copper is found attached to the cast-iron in flakes or sheets, and it is also on the bottom of the furnace in powder more or less fine. The sheet-copper attached to the cast-iron amounts to 70 per cent. of the total product, and contains only a trace of arsenic, and is sent at once to the operation of fining the rosettes, which contain only 0.039 per cent. of arsenic, while those of the former method contain 0.3 per cent. The fines, instead of going to the first fusion, as in the old method, are scattered in small quantities in the mattes in the roasting stalls. The following are the analyses of each of the products.

	Flake copper.	Fine copper.
Copper,*	87.41	57.95
Sesquioxide of iron,	3.40	10.95
Oxide of zinc,	0.50	1.78
Arsenic,	0.69	4.93
Alumina,	0.25	0.33
Lime,	2.	1.80
Sulphuric acid,	1.12	2.57
Water,	1.	3.83
Residue,	3.50	12.10
Total,	99.87	96.24

This furnace treats in a month all the waters required for 40 successive operations in the old apparatus. There is no trace of sub-salts, and the cement copper is much purer, and the whole of the liquor resulting from the precipitation of the copper is sent to be crystallized.

The quantity treated in 1875 was 513.89 cubic metres, which weighed 1.292 kilos per cubic metre. Its composition was

* Annales des Mines, 7th Series, vol. ix., p. 199.

	Before.	After.
Protoxide of copper,	1.38	0.06
Protoxide of iron,	6.91	8.72
Oxide of zinc,	1.78	2.32
Arsenic acid,	0.24	
Alumina,	0.66	0.74
Sulphuric acid with bases,	12.61	14.15
Sulphuric acid not combined,	2.08	0.65
Water,	73.68	72.48
Total,	99.34	99.12

The quantity sent to crystallization was 421.39 cubic metres, which weighed 1.294 kilos to the cubic metre. The amount of cast-iron consumed is reduced to 2.5 for one of copper. In the old method the largest part of the arsenic was precipitated with the sub-salts and whatever was not removed was contained in the iron sulphate. In the new process, the arseniates are reduced by the sulphurous acid to arsenites and during the cementation it is entirely precipitated as an impalpable powder in the 30 per cent. of the fines. As this is all carefully washed before it is used, it is for the most part carried off as an impalpable powder, as it is of much lighter density than the copper associated with it.

The work of the two processes is shown in the table below: *

	1874.	1875.
Cast-iron for one of copper precipitated,	3.27	2.55
Loss on the 100 kilos of copper contained in the waters,	16.40	7.60
Cubic metres of peat used,	3.13	1.93
Copper sulphate produced per cubic metre of liquid,	1.50	1.76
Sheets of copper of 85.9 of copper,		48.239
Yield of fine cement,	54.97	60.06
Sub-salts yielding 9.25 per cent. of copper,	24.840	

The saving effected was equal to 134.63 francs for each operation, and as 600 operations per year are made, the saving is equal to 80,000 francs a year. The treatment for the year 1875 was somewhat less than the average, as it was the year when the process was first introduced. Wood is used in the reverberatory furnace, peat and charcoal in the tanks. The expense is much larger

* Annales des Mines, 7th series, vol. ix., p. 198.

than in the reverberatory furnaces. The cement copper is washed several times by decantation. It is then allowed to remain fifteen days on the drying-floor to drain, and when dry sent to the black copper fusion.

At Skofie, in Carniola, Austria, the precipitation is done in revolving barrels, 4 m. in diameter, and takes 12 hours. As there is a minimum of air in these there are almost no sub-salts of iron precipitated. The amount of iron required then is 1540. kilos for every 1000 kilos of rosette copper produced, which is the least amount consumed by any of the other processes.

5. Crystallization of the Iron Sulphate.

From the cementation apparatus the clear water has been drawn off at 37° B., and at the temperature of 50° to 60° C., the muddy water at a temperature of 30° C. These waters contain iron sulphate, which is crystallized in wooden tanks of two sizes, 2.20 m. by 3 m. and 3.50 m. by 3.0 m., both being 0.50 deep. The clear liquid is run into the tanks immediately. The muddy waters are collected to be clarified before they are used. In these tanks the iron sulphate is crystallized by lowering the temperature and by slow evaporation. In winter the operation is very quickly effected because the waters pass rapidly to a low temperature. There is a very great difference in the solubility of the sulphate between zero and 50° C. The operation is generally effected in from 21 to 30 days. In summer it is effected very slowly, for the temperature does not go down below 30° C., so that the operation lasts a very long time. Generally the time required in summer is one month, and three weeks in winter. In order to hasten the crystallization, small brush is hung in the tanks, upon which the crystals deposit. It would be much better to suspend lead strips. The crystals which are formed on the brush and on the sides of the tank are quite pure and contain but little sesquioxide of iron. Those which are formed on the bottom are quite impure, the proportion of sesquioxide of iron being very much larger in the summer than in the winter on account of the longer exposure of the liquid to the air. To prevent this oxidation, the liquors are sometimes covered with planks or with sawdust. Three kinds of crystals are produced. Those

on the sides are the purest. Those on the brush are quite pure, but it is not possible to detach them without separating some organic matter at the same time. Those on the bottom are the most impure. These bottom crystals are always washed repeatedly with cold water to remove as much of the sub-salts as possible, such as are on the surface being washed off. Those which are in the interior of the crystals cannot be reached. When the crystals on the sides are well formed they are left for two or three successive crystallizations. They increase in size and become beautiful crystals. The crystals on the brush and on the bottom must never be left. The different kinds of crystals do not form in equal proportions. Those on the bottom comprise 60 per cent., those on the branches 20 per cent. and those on the sides 20 per cent. of those collected. When the solution marks 26° B., it is pumped out, as it is no longer worth saving.

The crystals are removed and washed with cold water to separate the mother liquor and then drained on inclined areas built for the purpose. They are packed at once to prevent deterioration. They still contain moisture, and 3 per cent. of their weight is allowed to the purchaser on this account. They are dried, packed and sent to Venice. About 600 tons of crystals are made in one year. The waters contain much more than this, but they are not worked to their capacity because there is not a market for any more. The composition of the crystal is:

Protoxide of iron sulphate,	49.73
Sesquioxide of iron sulphate,	3.20
Zinc sulphate,	4.45
Water,	42.50
	99.88

The absence of arsenic is remarkable. It has not been found as yet. It is probably all precipitated with the iron-compounds toward the end of the concentration. The crystals, which are perfectly pure, contain 58 per cent. of iron sulphate and 7 equivalents of water. Two men are all that are required to do the work, which realizes a large profit on the manufacture. The town is situated so far from the markets that this profit is for the most part swallowed up in transportation. When transportation is reduced in cost it can be made to yield a much larger profit.

DRY WAY.

The ores contain a certain proportion of arsenic, and when they are roasted the sulphur carries off some part as sulphide of arsenic, and towards the last part of the operation the arsenious acid, so that the interior of the kernels in the concentrated ores are almost entirely free from it. All the parts to which the air has access contain arsenic as arseniates of iron and copper. It is possible that a very little arsenic is lost in the roasting as arsenious acid, but the larger part is carried off as sulphide, and a certain portion of the arseniates of copper and iron are dissolved in the liquid because that is acid. In the precipitation of the copper by the iron, almost the whole of the arsenic is precipitated in the form of subarseniate of sesquioxide of iron. This will be thrown down with the cement copper and will in part be separated. The rest will pass in the treatment in the dry way with the rich and concentrated ores. The rich ores are not roasted, and consequently have lost none of their arsenic. The 1200 tons of concentrated ores contain almost no arsenic. The presence of this arsenic requires that the ordinary operations shall be conducted in a special manner.

First (6), a fusion of the rich and concentrated ores for matte in a very high furnace, so made in order to expel the arsenic. This produces a matte and scorias poor enough to be thrown away.

Second (7), roasting the mattes in stalls.

Third (8), treatment of the roasted mattes in shaft-furnaces, of which the products are *a*, black copper; *b*, a rich matte, which is roasted with the first ore; *c*, scorias rich enough to be fused in the shaft-furnace and passed to No. 1; *d*, scorias which are thrown away.

Fourth (9), fining the black copper in a low hearth, from which rosette copper is obtained.

6. Fusion of the Rich Ores, Kernels and Cement Copper for Mattes.

It is indispensable in the fusion for mattes not to obtain any metallic copper, for if any was produced it would contain a large portion of the arsenic, and the fining and refining would become almost impossible. It is therefore essential that the materials treated in this operation should have been roasted, and that a very

high furnace should be used to get rid of the arsenic as far as it is possible.

The furnace, Figs. 3 and 4, is nearly circular in shape. It is 8.60 m., in height and 1 m. in diameter above and 0.80 m. below. The tuyeres are 1.15 m. above the bottom of the hearth. It is not vertical, but has an inclination away from the breast at an angle of about 12°, so that the tuyere side stands inclined to the horizon at an angle of 78°. The object of this inclination is to make the gases follow the breast in order that the reducing action may be so

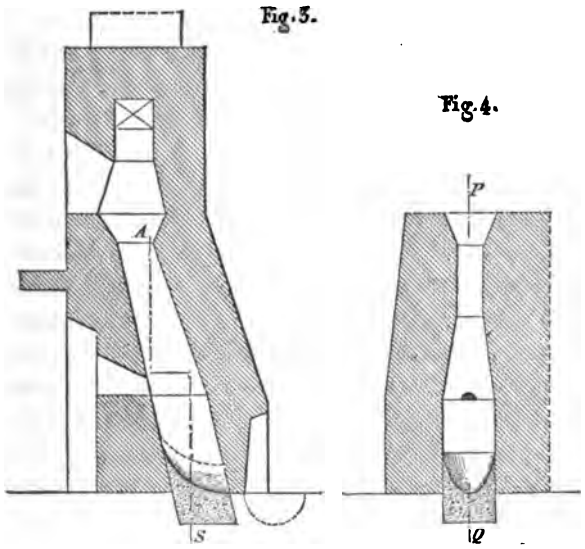


FIG. 3.—Vertical Section on the line P Q.
FIG. 4.—Vertical Section on the line A S.

feeble that iron sows will not be formed. It is not a good disposition and has been abandoned almost everywhere except here. It is just as easy to smelt in a vertical furnace, in which the formation of iron sows can always be avoided, by proper preparation of the materials which form the charge, before they enter the furnace, rapid action in the furnace and proper fluxing, and thus avoid the complicated construction, as the cost of both building and fire-bricks at Agordo is very high. The interior lining of the furnace is made of talcose slate, which is found in great quantities in the vicinity. It requires to be laid so that the pressure is at right angles to its lamination. It is not easy to cut, but makes a very

the breast is broken in at once in order to remove the deposits on the walls of the furnace while they are still hot, at which time they can be easily broken off. The interior is repaired, or if the corrosion is too far advanced, the in-walls are rebuilt, which must be done after several campaigns. The crucible is always made over after every operation. Engorgements are very rare in these furnaces. The side walls are rapidly cut out at the level of the tuyeres, so that the increase in the size of the furnace at that point, necessitates a constant increase in the quantity of fuel consumed, which at the end of the campaign will amount to about one-third more than that generally used. When the scorias become pasty, the furnace is blown out. Its great height causes a partial reduction of the iron oxides, but there is still sulphur enough in the charge to cause the whole of it to combine and thus cause it to enter the matte, which becomes all the poorer for this cause. The temperature of the furnace should never be high in front of the tuyere and from this point it should decrease rapidly to the throat. The blast is at quite a high pressure. The transformation of the carbonic acid into carbonic oxide must take place very near the tuyere, so that there is little carbonic acid left. The greater part of the sesquioxide of iron in the cement is reduced to protoxide, but a part of the sesquioxide passes into the slag before it reaches a temperature sufficiently high to be reduced. A very large part of it, however, is reduced to protoxide and passes as such into the slag. A part of the sulphur is volatilized and carries off arsenic with it as sulphide of arsenic. There is very little chance for any reaction of the sulphides and the oxides on the mattes and the scorias, since the scorias contain only .3 per cent of copper in the shape of grains. The working of the furnace is chiefly regulated by the indications which are furnished by the nose. The opening in the end should be bright but small; when it is in the proper state the scorias will run easily. If the end becomes dull the charge is not sufficiently heated, and there is danger that the opening will become closed. If it becomes brilliant, the opening enlarged, and it becomes studded with brilliant spots there is danger that it will be melted off, and the heat must be diminished. If it becomes melted, the whole charging must be suspended and the work of forming the nose be commenced as when the furnace is being put into blast. The following are the details of a usual campaign:

Quantity of rich ores, kernels and scorias treated in a campaign,	1600 to 2000 tons
Number of campaigns in a year,	9
Length of campaigns,	20 days
Quantity of charcoal,	621 tons
Red sandstone,	270 tons
Labor,	1440 days

The fuels employed are wood, at $2.1 the ton; charcoal, $11.5 the ton; peat, $2.2 the ton. The labor is paid at $0.24 a day. The amount of ore treated in one campaign was 1777.778 tons.

Charcoal, 69 tons at $11.45,	$790.05
Labor, 160 days at 30 cents,	48.00
Red sandstone, 30 tons at $3,	90.00
Repairs, etc.,	100.00
Cost of one campaign,	$1028.05

During this campaign there were treated, concentrated ores, 207 tons; rich ores, 19.60 tons. The product of the same campaign was 96 tons of mattes and the product of the same year was 896 tons of mattes. The yield of the matte was from 24 to 25 per cent. of copper. The composition of the matte is: copper, 24.10; iron, with a little zinc, 49.60; sulphur, 26.30; and the cost per ton of ore was $0.61. To the 896 tons of mattes of the fusion for mattes, the mattes from the fusion for black copper are added, so that the product becomes 1200 tons of mattes to be roasted.

7. Roasting the Mattes.

The roasting is done in stalls with 5 fires. The length of the stall is 3.6 m., the width 2.6 m. and the height 1.8 m. The number of stalls in two rows, 24; the charge in each stall, 8 tons; and the time required for the 5 fires, 14 to 16 days. The stalls are constructed of slate and have three walls. They are placed under a roof to protect them from the rain. On the floor of these stalls there is always a certain quantity of fine stuff and on this is placed any of the other fine material containing copper about the works. These are taken up from time to time and sent to the black copper fusion. The fuel is usually peat and an inferior quality of wood. The wood is placed on this fine stuff in the direction of the length of the stall to give air channels, and is then put across it. Above

this shavings are put, a little charcoal and then peat on top of all. A thickness of 0.20 m. to 0.30 m. of peat is used, but only on the first fires. The front of the stall is closed with large pieces of imperfectly roasted or of fused matte piled up as a wall. The upper part is covered with fine stuff. When finished it is about 1 m. high and contains 8 to 10 tons of ore. The matte undergoes five to six roastings. When it has been roasted once, it is picked over and what is not completely roasted is re-roasted in the second stall. For the second roasting, as the charge is difficult to light, more fuel must be used. For the third roasting peat is no longer serviceable, but only charcoal. For the 4th and 5th roastings, alternate layers of matte and charcoal are made; at one-third of the height of the stall one layer of charcoal and at two-thirds the other, making three beds of fuel. In all of these operations the roasting must be conducted very slowly. The matte is quite compact and the contact of the oxygen of the air with the matte is not very intimate. The roasting is consequently done with a minimum of oxygen. The heat is low and this method is therefore calculated to drive off the greater portion of arsenic. At the end of five fires the arsenic is considered as driven off. The outside of the pile is usually white from the vapors of zinc oxide produced by volatilization of the zinc resulting from the decomposition of the blende. It takes two days to each fire, the labor being 14 men for all the piles. Formerly the poor mattes were roasted to form copper sulphate and lixiviated, but the operation was performed under so many difficulties, required such close attention and it was so difficult to dispose of any but the best crystals, that it was abandoned and is no longer in use.

8. Fusion for Black Copper.

The shaft furnace used for the fusion for black copper is shown in Figs. 5, 6 and 7. It is inclined at 88°, as for the matte fusion, but the furnace is smaller. The whole of the inclined part is made of ordinary stone. The charge is made on a level with the throat on the tuyere side. The flames and the gases are carried off by chimney. The labor required is two men at the throat and two men below. These men work 12 hours. The roasted mattes contain principally iron sesquioxide, copper, zinc and iron, sulphurets and sulphates, and a very small quantity of arsenic. To

melt the sesquioxide of iron, the scorias from the fusion for mattes, quartz, and red sandstone are used. The charge is composed of roasted mattes, 95.146; refinery crasses, 2.257; scorias, 21; red sandstone, 2. The scorias which result should contain the whole of the sesquioxide of iron. The red sandstone contains no other base than peroxide of iron, but the scorias should be silicates of protoxide. There must therefore be a reducing action in order to convert the sesquioxide into protoxide. Care must be taken at

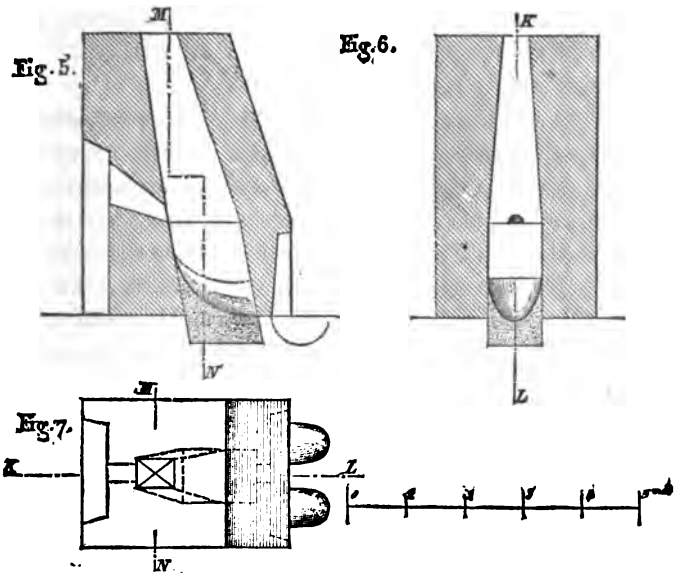


FIG. 5.—Vertical Section on the line K L, Figs. 6 and 7.
FIG. 6.—Vertical Section on the line M N, Figs. 5 and 7.
FIG. 7.—Horizontal Projection of Fig. 5.

the same time not to push this action far enough to reduce the oxide to metallic iron. The oxide of copper is reduced and a part of it passes into scorias, which must be impoverished by a longer contact with the mattes. The fuel is charged against the breast. The carbonic oxide which is produced in the combustion will follow along the breast, and consequently the reducing action on the materials against the tuyere side will be much less energetic than if the furnace had been vertical, in which case, with the slow action which is here used, the iron would have been reduced in large quantities. With this disposition the protoxide is made to

pass into the scorias and engorgements are prevented. The black copper obtained contains 95 per cent. of copper and but little iron. The scorias contain copper oxide, which in contact with the iron sulphide of the mattes makes the copper pass into the matte and the iron into the scoria. As all the scoria containing grains of matte are passed in the fusion for mattes, there is no very great objection in having a small quantity of copper oxide in the scorias, as it is regained in the matte fusion. The scorias are, however, never rich. The poor contain 0.5 per cent. and the rich 2 per cent. The arsenic is not entirely driven off. A small quantity is volatilized from the top of the furnace as arsenious acid, coming from the reduction of the arseniates.

The quantity of roasted matte passed in a campaign will depend on the way in which the operation is conducted and upon the manner in which the nose is formed. In order to have a complete separation of all the materials of the charge, they must be quite hot, so that the melted scorias are allowed to flow into the casting basin, where they separate easily by gravity. It takes four hours to fill this basin. The scorias are taken off from the top when it is full, as they cool. When the charge is ready, the crucible is emptied, the hearth is charged with fuel from the fore-hearth and the fuel is made to descend into it. The fore-hearth is then closed, the tap hole filled up, and the operation is continued. In the outside basin are the black copper, the mattes and the scorias on top. As the basin and the melted substances are very hot, they separate easily. The scoria is taken off in small disks as soon as it is cool enough. The matte, which contains 60 to 65 per cent. of copper, is grayish in color, porous and quite thick. It is quite free from arsenic. It is formed in very small quantities just above the black copper and is taken off in rosettes. The black copper is also sometimes taken off in rosettes, these are formed by throwing water on the surface of the melted mass, but it is often taken off with a ladle. It contains from 92 to 94 per cent. of copper. If in rosettes, they are broken at once while they are still hot. The scorias should contain 38 to 40 per cent. of silica. They must contain the iron as protoxide only. They contain a small portion of zinc and a variable quantity of copper. Those with which the basin is heated contain about 2 per cent. of copper and are sent to the matte fusion. Those taken from the outside basin are much richer and are put back at once into the charge. The campaigns of the furnace last ten days,

but on account of repairs only twenty campaigns can be made in a year. A great many attempts have been made to modify the shape and height of this furnace, but without success. Every attempt to alter it has resulted in a much more impure black copper. In some of these experiments the amount of iron contained in the black copper was such that it was impossible to refine the copper made. This is natural, for every one of the changes made increased the reducing action.

9. Fining and Refining the Black Copper.

Fining.

The black copper is fined in a low hearth which has the form of half an ellipse. There are two of these furnaces placed side by side. In front of them is a basin for cooling the rosettes. The hearth is made of brasque composed of 3 per cent. charcoal and 1 of red sandstone. The wear on it is so great that it has to be made over almost every day. The charge in each operation is 416 kilos. Only half of it is put into the furnace at first. The rest is added progressively. The operations are so arranged that one of the furnaces finishes its charge at the time the other commences. It requires from 1½ to 2 hours to melt the charge. The tuyere is horizontal, or at the most inclined 12° to 15°. Its end is only 0.15 m. from the charge. It is 0.04 m. in diameter. The blast is at a pressure of .055 m. of mercury. The rosettes or billets of copper fuse quickly. As they fall drop by drop before the tuyere the charcoal sinks and must be replaced, and the workmen shove up the copper towards the tuyere, so as to keep it always at the same distance until the charge is melted. At this time the tuyere is inclined so as to make the air strike the centre of the metal in fusion, and the fuel is separated so as to keep the metal melted but prevent any action of reduction. For this reason the blast oxidizes the foreign substances, and crasses rise and are removed as they are seen floating on the surface of the liquid metal. After they are taken off, this oxidation continues and brings other crasses to the surface from the oxidation of the iron and zinc and arsenic. This operation is repeated three to four times when the black copper is pure, and five to six when it is impure. Each operation lasts from three to four minutes and is repeated every quarter of an hour. During this interval, the charcoal is often pushed to

one side and the surface of the charge cleaned to see what is happening and to be sure that copper oxide is not absorbed to too great an extent. The crasses are very rich in copper and are sent to the matte fusion. The disengagement of sulphurous acid, from the action of the oxide on the copper sulphide, indicates the close of this operation.

Refining.

When the metal ceases to boil, assays are taken every five minutes. This is done with a polished iron rod, which is thrust into the bath of melted copper and then plunged into water. The thimble of copper which forms on its end is detached with a stroke of the hammer. The quality of the copper is judged of by the color of the inside of the thimble, which is smooth from its contact with the polished iron rod. It is first purplish. When it becomes copper-red with a slight tinge of purple the charge must be cast. If left to go on it becomes yellow from the absorption of copper oxide. When the color is right the blast is turned on to the neighboring furnace and the coals removed from this one. The charge is left ten minutes to cool down and then rosettes are made by allowing the metal to cool for 5 to 10 minutes and then throwing water on the surface. As soon as this has boiled off the rosette is taken off with a forked stick. The first and second rosettes are rejected to go to the next fusion. The others are sent to the storage houses or to be sold.

The time for taking off the rosettes depends on whether the copper is to be sold or is to be used in the works. If it is to be sold the refining is carried as far as possible so as to have the copper as pure as they can make it. If it is to be used at the works some oxide is left in them and the rosettes are carried to the storage houses, waiting the time when they are to be refined for use. When they are to be refined they are brought to the furnace. The finers have only to charge them. The furnace, having been previously repaired and dried, is filled with fuel in such a way that the air can penetrate it and half the pieces of black copper to be treated are charged. The blast is turned on. The black copper commences to melt little by little and falls in drops in front of the tuyere, where it is oxidized. At the end of half an hour the charge is in complete fusion. Half of the remainder, or one-quarter of the whole charge, is then added. This is melted in about half an

hour, and then the first two rosettes obtained in a previous operation, which are always rejected, are used. The whole operation lasts an hour and a quarter. From 30 to 40 rosettes 0.008 m. thick are made of a charge. This takes half an hour. The crasses are very rich and are sent to the fusion for black copper. The charge is melted in two hours; the crasses are formed during one hour; fining and refining takes one hour; making rosettes, one-half hour; total, 4½ hours. In the two furnaces, five operations are conducted in 12 hours. The loss is variable. 75, 78 and, rarely, 82 per cent. of fined copper are produced. The quantity depends on the purity of the black copper and the skill of the men. The number of men required are finers 2, assistants 2, they work only by day. 14 tons of fined copper are obtained. The loss is always 2 per cent. or ⅛ of the total product.

To produce a thousand kilos of rosette copper in 1872 there were used:

Copper in the ore,	1412 kilos
Iron,	2750 kilos
Sandstone,	4160 kilos
Wood,	1.90 cubic metres
Peat,	19.10 cubic metres
Charcoal,	34.40 cubic metres *

If these expenses are compared with those of the ordinary treatment, the expense in fuel will be found to be less. The principal burden of the expense is found to be the high price of cast iron. It is here worth $45 per ton when it costs $30 elsewhere. The number of days' work required is more than in the ordinary treatment. The total cost is not, however, greater, for many of the days counted are days of children's work employed in picking the ore.

The ores contain 50 per cent. of their weight in sulphur, and for 15,000 tons treated there would be 7500 tons of sulphur. It is not possible to extract nearly the whole of this, as part must be left to be made use of in the processes in the dry way in order to form mattes. 20 per cent. would be sufficient for this process, so that 30 per cent. might be made use of. In order to do this, it would be necessary to have a manufactory of sulphuric acid and

* Church's Metallurgical Journey in Europe, p. 15, N. Y., 1873.

chemical products near the works. Transportation to market at Agordo is difficult, and they are therefore obliged not to attempt to save a large quantity of the sulphur, the loss of which amounts to a number of thousand dollars yearly. If the means of transportation were facilitated, they would far outweigh all the advantages of the metallurgical processes. The whole of the copper is not extracted. There are only 37 to 38 tons separated from the 1400 tons of roasted ore. Of these 1400 tons, 1300 tons are treated in the wet way. It is not known with absolute certainty how much the ores contain or how much is lost in the residues, but it is supposed that as much is lost as is extracted. In the other case where this process is used, much more is lost than at Agordo. The cause of the loss is the adherence of the copper sulphate to the iron sulphate. In the laboratory it is almost impossible to wash out from one gramme of iron sulphate which has been immersed in copper sulphate all the copper which it contains, and this is even more true on a large scale.

The cost of treatment is extremely small, which is owing to the fact that after the first roasting the larger part of the poor ores are separated and are passed to the process in the wet way, only one-tenth being treated in the dry way. This is the most inexpensive concentration of ores known. The cost of the extraction of the ore is about $2.40 the ton. The general expenses are very complex, for the Government gives help to the sick and pensions to the invalided, which would be included in the expenses.

A CONTRIBUTION TO THE THEORY OF JIGGING.

BY PROF. H. S. MUNROE.

SINCE the publication of the preliminary note on the movement of solid bodies in water, in the January number of the QUARTERLY, additional experiments have been made, tending to confirm the accuracy of the provisional formulas therein given. These additional experiments have also developed more clearly the laws governing the movement of grains in the interstitial channels, and *en masse*, and throw considerable light on the working of jigs. The details of this investigation will be published in full in another

place,* and it is proposed in this paper to give simply an outline of the results obtained.

Movement of Spheres En Masse.

It has been shown that the resistance to the fall of a sphere in a confined channel may be expressed by the following formula:†

$$R = \frac{1}{2}, \frac{\pi d^2}{4}, \frac{V^2}{2g}, \left(\frac{1}{1-\left(\frac{d}{D}\right)^{\frac{3}{2}}}\right)^2 \gamma \quad . \quad . \quad . \quad . \quad 8.$$

From this we obtain

$$\frac{d}{D} = \left(1 - dV\sqrt{\frac{\pi\gamma}{16g}\cdot\frac{1}{R}}\right)^{\frac{2}{3}} \quad . \quad . \quad . \quad . \quad . \quad 10.$$

A series of experiments were made to determine the velocity of current required to hold a mass of grains in suspension. These experiments were made with shot of different diameters, with mixed shot, with angular grains of galena, and with rounded grains of the same mineral.

In these experiments the resistance, R, is the weight of the single grain in water. The average diameter of the shot or grain of galena is d, and D is the diameter of the tube or channel in which the grain would be supported by the observed velocity, V.

In the first series shot were used, varying in diameter from 2.5 mm. to 3.8 mm. Each experiment was made with shot as nearly as possible of uniform size.

Making the proper substitutions in formula 10, the following value was obtained as the mean of a large number of experiments:

$$\frac{d}{D} = 0.89.$$

Practically the same result was obtained for the large shot as for the smaller sizes. The above result indicates that shot moving *en masse* follow the same law as already developed for shot moving in tubes. A mass of spheres of uniform size occupy 70 per cent. of the total volume in which they are contained. If we assume that the average diameter of the interstitial channel in which each

* Trans. Am. Inst. of Mining Engineers, vol. xvi.

† QUARTERLY, vol. ix., No. 2, p. 142.

grain moves is proportional to the cube root of the relative volumes of sphere and total space occupied, we shall have

$$\frac{d}{D} = \sqrt[3]{0.7} = 0.89.$$

or the same value as deduced from the experimental results. Substituting this value in equation 9,* we will have *for spheres of uniform size, falling en masse,*

$$V = 0.833 \sqrt{d(\delta - 1)} \quad . \quad . \quad . \quad . \quad 11.$$

Mixed Spheres of Different Diameters.

If we take the case of a mixed mass of spheres of different diameters, it is evident that the interspaces between the large spheres will be filled in part by the smaller spheres. If there be considerable difference in the size of the spheres in the mixture, the small spheres will occupy not less than 70 per cent. of this interstitial volume. In such case the ratio of the volume of the large spheres to the interstitial space in which they are contained will be as 0.70 : 0.79, or 0.886. On this basis we shall have *for large spheres surrounded by small ones,*

$$\frac{d}{D} = \sqrt[3]{0.886} = 0.96.$$

Some experiments were made with mixed shot, and with large shot surrounded with small ones. In the latter case the large shot were suspended from the spring balance, so that the buoyant effect of the current could be measured. Values for $\frac{d}{D}$ were obtained, varying from 0.93 to 0.94, the values increasing regularly with the difference in diameters of the large and the small shot. So far as the experiments go, they tend to confirm the theoretical value above deduced; viz., 0.96.

Substituting this value in equation 9, we will have *for large spheres falling in a mass of smaller spheres, when the difference in diameter is considerable,*

$$V = 0.307 \sqrt{d(\delta - 1)} \quad . \quad . \quad . \quad . \quad 12.$$

* QUARTERLY, vol. ix., No. 2, p. 143.

Equal Falling Spheres.

If now we determine the diameters of equal falling spheres of quartz and galena, on the supposition that the large spheres of quartz are surrounded by smaller * spheres, while the small spheres of galena are surrounded by spheres of equal size, we shall have

$$0.307 \sqrt{d\,(2.6-1)} = 0.833 \sqrt{d_1\,(7.5-1)}$$

$$d : d_1 :: 31 : 1. \quad . \quad . \quad . \quad . \quad . \quad 13.$$

We see, therefore, that if the material to be treated be sized between the limits 1 mm. and 30 mm., it will be possible to separate the quartz from the galena. All the spheres of galena will have a greater falling velocity that the 1 mm. grain, and all the spheres of quartz will have less falling velocity than any of the spheres of galena.

On the basis of the old formulæ for free falling bodies, the ratio of equal falling spheres of quartz and galena is 4 : 1.

Rounded and Angular Ore-Grains.

Experiments were made with angular grains of galena and with rounded grains of the same mineral.

For rounded grains of uniform size, falling en masse:

$$V = .490 \sqrt{d\,(\delta - 1)} \quad . \quad . \quad . \quad . \quad 14.$$

For angular grains of uniform size, falling en masse:

$$V = .536 \sqrt{d\,(\delta - 1)} \quad . \quad . \quad . \quad . \quad 15.$$

Effect of Increasing Velocity of Current.

Experiments were made to test the effect of stronger currents upon a mass of grains. When the velocity of the rising current is increased beyond that necessary to hold the mass of grains in suspension, the effect is to lift and separate the grains, and thus decrease the ratio $\frac{d}{D}$ until a state of equilibrium is reached. A very slight separation of the grains, with a corresponding small decrease in the ratio $\frac{d}{D}$ makes necessary a large increase in ve-

* Qy. Is there sufficient difference in the diameters of the spheres in question to give the extreme value of $\frac{d}{D}$ assumed in equation 12?

locity. With a given velocity of rising current the mass of grains under normal conditions will rise to a certain height, and no higher. In the small tube in which the experiments were made, an arch of grains sometimes formed across the tube, and in such cases the whole mass would rise like a piston. This, of course, would not take place in a larger tube, nor on the sieve of a jig.

Effect of Diameter of Spheres.

From formula 9,

$$V = 5.11 \left(1 - \left(\frac{d}{D}\right)^{\frac{1}{2}}\right) \sqrt{d(\delta - 1)},$$

we see that with equal ratios for $\frac{d}{D}$ the falling velocity increases with d, or with the diameter of the sphere. It was noticed, in the experiments with mixed grains, that the continued action of the rising current gradually effected a separation according to size; the larger grains settling to the bottom, and the smaller grains finding their way to the top. The same result will be produced by the continued action of the intermittent rising currents of a jig, and also during the fall of the grains in the period of still water between the strokes. This will not interfere with the separation of the two minerals, but, on the contrary, will rather facilitate the separation of the large grains of quartz, which will be surrounded by small grains of galena.

In the English method of jigging through a bed and through the jig-sieve, it is the common practice to have downward currents alternate with the rising currents, in order to facilitate the passage of the fine galena through the bed.

Effect of the Irregularities of the Interstitial Channels.

A series of experiments were made with an artificial interstitial channel. A negative was made by pressing spheres two inches in diameter into a core of wax. The wax core was suspended in a tube which was then filled with plaster of Paris. After the plaster had set, the tube was heated, melting the wax and leaving a perfect reproduction of an interstitial channel in the tube. The cross-section of this channel varies at different points. At the places where the spheres are in contact it is quite small, while between

the points of tangency its area is much enlarged. With perfect spheres the maximum area of the interstitial channels is about 40 per cent. of the total area, and the minimum area about 10 per cent. The velocity of the rising current thus varies between two and a half and ten times that of the whole area of the jig-sieve. The equivalent diameters of the channel at the narrowest and widest places, are about one-third and two-thirds respectively of the diameters of the spheres forming the channel. The lifting effect of a rising current in such a channel varies between wide limits. Experiments show a buoyant effect five times greater in the narrow part of the channel than in the widest place. This fact perhaps explains the imperfect action of jigs on the finest stuff. The descending grains of the heavy mineral have to pass the narrow portions of the interstitial channels, where the lifting effect is greatest; and the light grains have to be lifted through the widest places in the same channels, where the current has its minimum effect.

In practice, with angular and rounded ore-grains, the variations in the size of the interstitial channels is less pronounced than in the case of perfect spheres.

The larger ore-grains are in contact with the surrounding particles, and thus determine, to a certain extent, the size of the interstitial channels in which they move. The irregularity in the diameter of the interstitial channels will therefore affect the very finest particles only.

Effect of the Size of the Mesh of Jig-Screens.

In the treatment of unsized material on a jig, the size of the mesh of the jig-sieve will have an important influence on the result.

1. The mesh of the sieve must bear a definite relation to the coarsest grain of ore, in order to limit the range of size treated.

2. The mesh of the sieve will determine the size of the smallest grains in the jig-bed, and, therefore, the size of the interstitial channels left by the sifting through of the finest material.

3. The mesh of the jig-sieve thus indirectly determines the extent to which fine material can be treated.

It is evident that material of less diameter than the grain of maximum velocity, that is, grains less than four-tenths the diameter of the smallest interstitial channels, cannot be treated to advantage.

It is also evident that grains minute enough to move freely in the small interstitial channels will be affected by the irregular size of these channels, and cannot be treated to advantage.

Practical Illustration.

The roughing-jigs in the mill of the St. Joseph Lead Co., at Bonne Terre, Mo., treat unsized stuff from 4 mm. to the finest slime.

The pistons of these jigs make 150 strokes, 2″ long, per minute. The area of the piston is about one-third the area of the jig-sieve. The amount of under-water is but little in excess of that discharged with the hutchwork, and has but little effect on the velocity of the jig-currents. The rising current is therefore that due to the movement of the piston, or about 0.08 m. per second. This, according to formulæ 14 and 15, will raise a 4 mm. grain of galena. The downward current has about the same velocity. The jig-sieves are of No. 6 wire-cloth, with about 2.8 mm. openings. The grain of maximum velocity is one-eighth millimetre. This was determined by observing the relative amounts of each size passing through the sieve, and going over the sieve, respectively. Tailings finer than this show free galena, though the loss is not serious above one-twelfth, or perhaps, one-sixteenth millimetre. The hutchwork begins to be poor, indicating imperfect concentration, at about one-quarter millimetre.

The finishing jigs at the same mill treat stuff one millimetre and less in size. The jigs are run at 270 strokes, one-quarter inch long, per minute. The jig-sieve is of No. 8 wire-cloth (2 mm.). These jigs treat successfully stuff one-twentieth mm. in size.

It will be seen that these results tend to confirm the laws developed by this investigation. The concentration is quite satisfactory, and there is no loss in free galena except in the very finest material, stuff fine enough to be affected by the irregularities in the smallest interstitial channels;* and so fine as to be smaller than the grain of maximum velocity.

The range of size treated successfully on these jigs, without loss

* In computing the probable size of these smallest channels, it must be remembered that the stuff sifts slowly through the jig-sieve, so that there is always material in the bed much finer than the mesh of the wire-cloth.

of free galena in the tailings, is from 4 mm. to 1/8 mm. in one case, and 1 mm. to $\frac{1}{20}$ mm. in the other; or 1 : 32 and 1 : 20 respectively.

Rèsumè.

The following are the main points which have been developed in this investigation:

1. A sphere falling through a column of water in a tube falls at first with accelerated velocity.

2. The resistance increases with the square of the velocity, and is expressed by formula 8.

3. The sphere finally falls with uniform velocity, which is as given in formula 9. A rising current of equal velocity will just support the sphere. A current of greater velocity will cause the grain to rise.

4. A sphere four-tenths the diameter of the tube will fall with maximum velocity, and will require a current of maximum velocity to support or raise it.

5. Grains moving *en masse* are really moving in confined channels, and follow the law developed for movement of bodies in tubes.

6. In a mixture of grains of different sizes the large grains move in relatively smaller channels than the small grains, so that the equal falling ratio in the case of quartz and galena is 1 : 31 instead of 1 : 4, which would be true if the grains were falling under similar conditions.

7. If the velocity of the rising current, acting upon a mass of grains, be increased, the main effect is to separate the grains until by the change in the ratio $\frac{d}{D}$ a new condition of equilibrium is reached.

8. The separation of the very finest stuff, grains fine enough to move freely in the smallest interstitial channels of the jig-bed, is likely to be imperfect and unsatisfactory. In practice, it is found that there is in each case a very sharp line, below which it is not advisable to treat the fine material on jigs.

9. By the system of jigging without preliminary sizing (except so far as necessary to remove the very finest slimes), it is possible to treat fine material successfully on jigs, which has heretofore been treated with success only on tables or other slime-washing apparatus.

THE THEORIES FOR RETAINING-WALLS.

BY PROF. R. H. THURSTON.

THE paper of Professor Merriman on Retaining-Walls,* and especially its last paragraph, suggests considerations that I have been for some years past accustomed to lay before my own classes, and a method of treatment which I think meets the demand of the practitioner, even though its theory of distribution of stresses within the mass of earth be not positively exact.

Consider the actual conditions existing behind any retaining-wall after the earth has settled into place and a few seasons have passed, with their variations of temperature and humidity, and after, perhaps, thousands of trains have rumbled past, each giving the earth such a general shaking as no amount of hand work can give. The soil, originally carefully laid in place and well tamped, presses from the first against the back of the wall with much more force than any theory of simple weight-pressure would give. Every change of temperature, and every alternation of freezing and thawing, produce an alternate expansion and subsidence of the mass, while the action of every jar is to shake the particles down and to wedge them among each other by just the amount which the simultaneous plus and minus action of friction among them may produce. Thus continually, day by day, weeek by week, and month after month, through a series of years, the whole mass is being first reduced to a smaller compass, and then, by its expansion, caused to swell and press against the rear of the wall with a force which, as a maximum, is just that which would be required, were the wall set on a frictionless base, to force it back slightly into the mass of soil behind it. This maximum pressure is that which every wall must be calculated to withstand; and this pressure is enormously greater often, and probably generally, than that computed on the assumption that the soil settles against the wall, producing a pressure due to the action of gravity only.† Thus, the case is vastly different from that commonly assumed in

* See preceding number of the QUARTERLY.

† Friction and Lost Work. R. H. T. New York: J. Wiley & Sons. 1885.

theories for retaining walls, and the pressure to which they are subject, instead of being less than where a fluid is sustained, is greater in the proportion by which the internal friction of the mass intensifies that pressure, as just indicated. It may be many times as great as the usual calculations would indicate, and, instead of the friction of the soil reducing its amount, it may enormously increase it. It is this which, as I am inclined to think, accounts for the difference between the real and the hypothetical case observed by that experienced and very accurate observer and engineer, Trautwine, and which led him to assert the absolute valuelessness of all theories for such cases.

Trautwine would make the thickness of the wall at least one-half or one-third its height, according to the character of its construction, thus giving a factor-of-safety of from 6 or 8 up to about 20, instead of 2 or 3. His experience, as he stated, indicated that the customary theories and rules of the text-books on this subject were worse than useless; were simply dangerously misleading. The accepted theory would make the pressure on the back of the wall less as the co-efficient of friction of the soil is the greater. The actual case would seem to be, precisely the reverse, and the pressure, as a maximum, during periods of expansion and contraction, by change of temperature or by jar, would be the greater when the co-efficient becomes increased. The difference is measured by that of the functions $\frac{1-\sin\theta}{1+\sin\theta}$ and $\left(\frac{1+\sin\theta}{1-\sin\theta}\right)^2$. The pressure on the retaining-wall should be computed as for a foundation. Rankine gives the correct process for the latter case, and values of the above expressions with various assumed values of θ.* On studying these values it will be seen that for very common figures for the co-efficient of permanent rest of ordinary soils the probable pressures are 5 and 10 and even 20 times those obtained by the old theory. Walls designed on that theory may well be expected to fall; those designed on what the writer supposes to be the more correct system would as certainly stand. The difference in theory corresponds to the differences noted by Trautwine in practice. It is very possibly exactly the difference between right and wrong.

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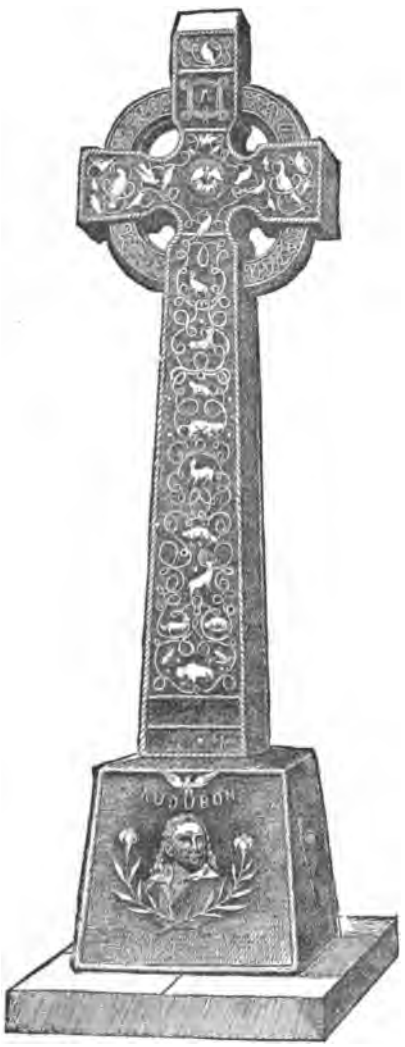
* Ibid., p. 232; Rankine, Rules and Tables, p. 182.

THE PROPOSED AUDUBON MEMORIAL.

It is proposed by the lovers of natural science to place over the grave of Audubon, in Trinity cemetery, a monument which shall be worthy of all that he accomplished for natural history in this country, and shall perpetuate to some extent the discoveries which he made. For this object a committee of the New York Academy of Sciences was organized in the month of October, who have associated themselves with a number of natural history societies of the country to raise funds for this monument. The monument, as the cut shows, is to be a runic cross, placed on a base six feet high. The shaft of the cross is to be eighteen feet above the base. It is to be ornamented with the birds and beasts which Audubon loved, and which he described so well. The cross is to be of North River blue stone. The base is to be ornamented upon one side with Audubon's gun and game bag, he being one of the best shots of his time, and on the front, with a bust of himself surrounded with the water-lily, which he discovered in Florida. On the opposite side is to be a suitable inscription. This monument will cost about $10,000, and subscriptions are being solicited throughout the United States, for the purpose of erecting it.



Audubon died in the year 1851, in the seventy-first year of his age, and was buried in Trinity cemetery, near One Hundred and Fifty-third street. The spot where his remains lie is but little visited, and on this account the authorities of Trinity cemetery have been induced to give a new plot in the cemetery, on One Hundred and Fifty-sixth street, at the foot of Audubon avenue, overlooking the site of his old homestead. The new plot will be ready some time in the early summer, and it is hoped that funds sufficient for the monument may be raised by next fall.

The Committee of the Academy of Sciences consists of Dr. Egleston, Chairman; Dr. Britton, Secretary and Treasurer; and Dr. D. S. Martin, and is co-operating with other committees in all parts of the United States. Subscriptions in aid of the monument fund may be sent to Dr. Britton, Treasurer, at Columbia College.

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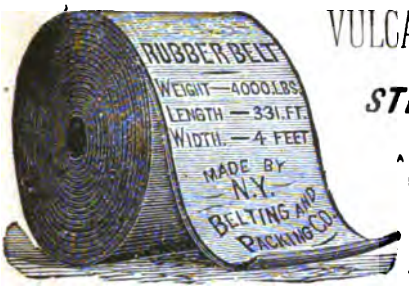

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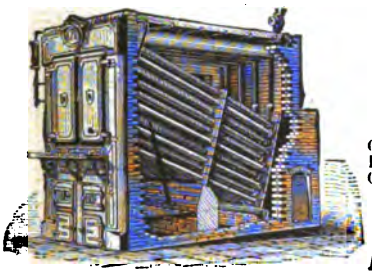

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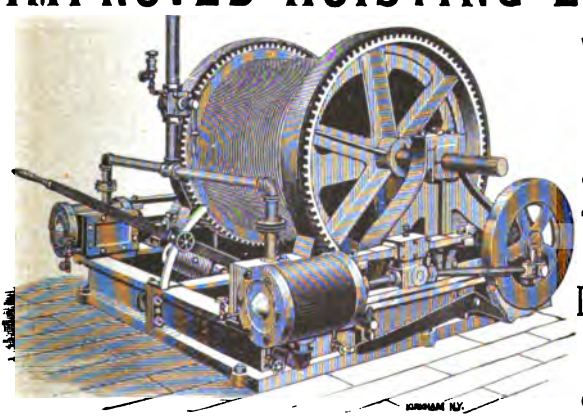

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SYSTEMS OF WEIGHT AND MEASURE.*

BY PREST. F. A. P. BARNARD, LL.D., D.C.L.

(Concluded from page 212.)

I HAVE thus pointed out certain powerful influences, influences which have sprung up from nothing since this century began, and chiefly within the last thirty or forty years, the tendency of which is to obliterate needless differences of social usages and institutions between families of the same common race, to efface as much as possible the boundary lines separating nations, and to secure ultimately the universal recognition of the great principle of the solidarity of peoples. These influences, combined with others more specific, which I have yet to mention, have already been so efficient in their action upon the Ciscaucasian group of European nations, as it respects the standards by which material quantities are to be dealt with—as it respects in short, weights and measures—as already almost completely to have exterminated the perplexing variety of metrological systems heretofore prevailing among them, and to have replaced them all by the metric.

The population of Europe, excluding Russia and Turkey, is about 220,000,000. Of these 140,000,000 have adopted the metric system in fact, and about 35,000,000 more people of the Austrian empire may be said to have adopted it in prospect. There remain fewer than fifty million, and of these the continental portion, Den-

* Lecture delivered at Columbia College, January 28th, 1888.

mark, Sweden, and Norway have advanced so far in the way of metrological reform as to decimalize their old systems, while the pressure on the Parliament of Great Britain is so steady and so strong, as to make the introduction of the metric system in the British Islands, where its use is already lawful though not compulsory, a question no longer of probabilities but of time. A royal British commission on the standards, the Astronomer Royal, Mr. Airy, being chairman, reported in favor of the system in 1869, and their published report embraced an elaborate argument by Mr. Chisholm, the Warden of the standards, urging that in view of the rapid and wide extension of the system over the continent, Great Britain could not, consistently with her interests, longer defer this important measure.

In like manner I urge that the time has come, when we too must look at this matter with a view to corresponding action on this side of the Atlantic. I speak here as if nothing had yet been done in this way on this side of the Atlantic, because our own country has done nothing yet worth naming, and our own country so overshadows the rest of the continent, that whatever the rest may do scarcely counts; yet this mode of speaking is unjust; for nearly or quite every government between us and Cape Horn has anticipated us in this matter. The metric system has been adopted by Mexico, New Granada, Ecuador, Brazil, Peru, Uruguay, the Argentine Confederation, and Chili. It is, therefore, already the system of twenty-five millions of people upon the American continent.

In saying, therefore, that the time has come when we ought to make preparation for the introduction of the Metric System into the United States, I am simply saying that we ought to prepare to meet our manifest destiny. I am not arguing in favor of the system upon its proper merits in the least—I mean I am not doing this, and I have no intention of doing this here and now. That argument can be made strong, conclusive, overwhelming if you please, but I have not time and you would not have patience for it here. I say we should prepare for it, because it is always wise to meet our manifest destiny cheerfully; and it is never very wise to resist. Mrs. Partington with her broom kept out the Atlantic Ocean for a time; but in the long run the Atlantic Ocean was too much for Mrs. Partington. We shall receive the Metric System at last. We might as well make up our minds to it now.

Perhaps you will inquire of me, what is the Metric System? Although I insist that we should adopt it, I do not know that I have even time to tell you that. This is a metre—this is a yard—the metre is a little more than three inches in excess. The metre is divided into ten decimetres, one hundred centimetres and one thousand millimetres. This is a decimetre. Three decimetres make a metric foot. This is the foot of Switzerland and Baden. Here is the foot metric and here is the foot British or American. The difference you see is trivial—not two-tenths of an inch.

From this metre are derived measures of surface, of solidity, of capacity, and of weight. The square of the metre is the unit of surface, the cube of the metre is the unit of solidity, the cube of the decimetre is the unit of capacity—a little over a quart, called the litre, and the weight of a litre of pure water at 39° F. of temperature is a kilogram, the unit of commercial weights. This is about two pounds and a fifth. Switzerland uses a half kilogram under the name of pound—and the same is true of several German states.

This metre is the ten-millionth part of the distance from the earth's equator to the pole, as nearly as human skill can ascertain that distance. The grand measurement of an arc of the meridian by which this determination was made, occupied the illustrious geodesists Delambre and Méchain seven years. The object of all this labor was to found the system upon the basis of a dimension in nature absolutely invariable. When we look round us to find some such dimension, it surprises us to discover how limited is the room for choice. The length of the pendulum beating seconds presents itself as one such; but then the length of the second's pendulum varies in different latitudes, and even in different longitudes; and apart from that it is a length so difficult to find anywhere experimentally, as to be practically good for nothing as a standard. For it must be considered that when we talk about the verification of standards, we esteem differences which seem to the common mind ridiculously small, to be grave errors. In a comparison of a metre bar now in the possession of the United States Coast Survey with the platinum standard in Paris, a comparison which I was charged with making in 1867, the directly observed difference was only $\frac{7}{100000}$ mm., or $\frac{1}{360000}$ inch, a quantity totally imperceptible except by the aid of the wonderfully delicate apparatus used for the purposes of the comparison, in which magnify-

ing powers both mechanical and optical were used in combination. The pendulum was made the standard of reference for the length of the yard in England by an act of Parliament passed 1824, but when, in 1834, the standard bar of the Exchequer was destroyed by fire, it was restored without any regard to the pendulum by reference to copies previously made.

Another natural standard which has been proposed is the velocity of light—that is the distance over which light is propagated in a second. This is enormously great, 180,000 or 190,000 miles; and our knowledge of it is dependent on our knowledge of the earth's dimensions, which makes it subject to the same uncertainty as the metre. Another still is the length of an undulation of light, which may be taken at a mean to be $\frac{1}{39000}$ inch. Whatever error there may be in the determination of this will be multiplied of course, nearly two million times in the length of a yard. On the whole, there seems to be no eligible natural standard, unless it be some dimension of the earth. The best, perhaps, would be the earth's axis; the French chose the quadrant of the earth's meridian. It will always be more or less an objection to either, that there is no means of determining it with absolute exactness.

I do not argue in favor of the metre because it is a ten-millionth part of the quadrant. The question whether it is truly so or not is not one worth considering; for those who say it is not have no proof that it is not, and in the nature of things they can have none. They argue only upon the balance of probabilities.

The true argument in favor of the meter is that it is the accepted basis of the metrology of Europe, of South America and Mexico, and of British India; of, in all, say about 480,000,000 of people, of whom nearly 200,000,000 are Christian inhabitants of the European continent. So much for the progress which this system has already made. Now when, in addition to those influences above mentioned favoring the assimilation of usages generally among peoples, we take into consideration certain additional and powerful influences favoring the unification of weights and measures in particular, it will be seen that our argument in favor of the metric system reduces itself to this: It is morally certain that uniformity of systems of metrology will ultimately prevail among all civilized peoples. It is morally impossible that the tendency of the metric system to extend itself can be successfully resisted. Therefore it is our duty to pave the way for the introduction of this system among ourselves by every means in our power.

The particular influences favoring the system just spoken of may be briefly enumerated. In the first place, the science of the world has adopted the metric system. Nowhere, except in England and the United States, are any weights or measures but the metric employed in scientific journals, scientific transactions, or scientific books. And our own country and England are rapidly falling into the common usage. Not a word need be said as to the importance to science of a common system of standards. Such a system is indispensable in order that scientific men may understand one another.

The next influence to be mentioned is that of the social science organizations. In just now using the word science without any qualification, the sciences which treat of force, motion, and the classification of natural things, were of course intended. Social science is something quite different from this. Its object may be generally stated to be the amelioration of the condition of the human race. Its devotees are therefore men who pursue their investigations in the spirit of benevolence, and who aim, by the diffusion of information among the people, and by the force of argument and the power of moral suasion, to lead men to amend their institutions wherever they appear to be defective. National associations for the advancement of social science exist in different countries, and there is also an international social science association, attended by delegates from most European states and from the United States of America. The influence of all these bodies, and, considering the character of the men who compose them, it is a powerful influence, is enlisted in behalf of uniformity of usages, of institutions, and of laws among the nations. The international organization has undertaken to prepare a code of international law to be presented for acceptance to the governments of the several powers, in the hope of settling definitely the rights and the mutual obligations of nations in peace and in war. And this body recommends the universal acceptance of the metric system of weights and measures. This recommendation is not more important from the weight it will carry, than from the indication it affords of the manner in which this important social and political measure is regarded by the most thoughtful men of every land.

A third influence conspiring with those already mentioned, is found in the results of international conferences which have been convened by the governments of Europe and of the United States,

for the express purpose of deliberating on the best means of reducing to uniformity the various existing systems of weights and measures and moneys. Such a conference was held in Paris in 1867, attended by delegates from twenty-two independent powers, among which were represented the non-metric nations, Russia, Austria, Sweden, Norway, Denmark, Great Britain, the United States, and Turkey. This body reported unanimously and strongly in favor of the universal adoption of the metric system.

Another influence more powerful than this, or than any of those mentioned before, proceeds from an organization, also created by the common consent of the various governments and likely to be permanently maintained, called the "International Statistical Congress." Eight meetings of this important body have now been held, the earliest in 1853 and the latest in 1873. Its labors have been specially directed to the investigation of the material and social condition of all nations, to serve as a preliminary to the recommendation of measures for the promotion of the general welfare. Its members have not failed to interest themselves deeply in the subject of the unification of moneys, weights, and measures. As it respects the latter; viz., weights and measures, they have found it absolutely necessary, for the proper prosecution of their own work, to adopt a common system, since they propose to publish a most voluminous exhibit of the material conditions of all nations, in which the statistics of the production, accumulation, and exchange of wealth in all its forms and in every country shall be fully set forth. In this immense work it is the resolve of the Congress, that all quantities of every description shall be stated in terms of the metric system of weights and measures only.

In reference to this important body I venture in conclusion to repeat here a few words which I have written elsewhere.

The "International Statistical Congress" may now be regarded as an established institution. Already the influence of its deliberations, of the published results of its labors, and of the spirit of comprehensive statesmanship which it has inculcated and fostered, is beginning to be sensibly felt, and with each successive decade of years it will be felt with a power continually increasing, in educating the minds of the peoples, and in moulding the counsels of governments into harmony with the great principle that nations only then consult their truest interests when they consult the common interests of humanity.

The germ idea of an agency which, with time, has developed itself into a power capable of controlling, and destined so largely to control the future of human history, is to be found in the report of Mr. Adams to the House of Representatives of the United States Congress, made in 1821, which has been already mentioned. Though this report discouraged the adoption of the metric system by Congress, and though its reasonings had the effect undoubtedly to impress the popular mind in this country with the conviction that the introduction of the system into these States is hopeless, yet the author himself was as deeply imbued with admiration of this system, considered as a scientific creation, as the warmest of its advocates; and no one felt more profoundly than he, how great would be the boon to humanity if one uniform system of weights, measures, and moneys could be made to prevail everywhere throughout the world. In the view of his large and statesman-like intellect, very many of the embarrassments which attend intercourse between nations spring from the selfish and narrow legislation which looks only to the immediate interests or convenience of particular communities, and disregards the results to the great family of man. To him all nations and all races are brothers by blood, inheriting the earth as their common patrimony; and though, in the existing state of human society, it is necessary that the artificial lines which divide states from each other should be preserved, it is eminently desirable that, for as many purposes as possible, they should be kept out of sight. He, therefore, proposed that the President of the United States should be authorized to invite the governments of the several states having diplomatic relations with that of the Union, to appoint delegates to a congress of nations, charged with the duty of deliberating upon measures likely to be promotive of the general welfare; but, foremost and especially, upon the possibility of establishing a uniform system of weights and measures for all mankind. That this important proposition was productive of no immediate result, is attributed by Mr. Ruggles, and with apparent justice, to the political condition of Europe during all the earlier portion of this century; and especially to that compact of political rulers for the suppression of liberal thought, and the stifling of all freedom of political discussion, which the momentous events of recent history have since shattered, known as "The Holy Alliance." Happily, however, at length, to use the vigorous words

of Mr. Ruggles, "We find the germ of the general convention, planted by the far-seeing sagacity of Mr. Adams in 1821, though slumbering for a generation beneath the surface, actually fructifying in 1853, when the first general assemblage of nations by government delegates, and really international in its objects, was convened in Brussels."

From this epoch dates a new era in the history of the world's legislation. For the enlarged views of the reciprocal duties, as well as of the true interests of nations, in which this great general movement originated, are destined, through its instrumentality, to impress themselves more and more completely upon human institutions; until statutes shall at length cease to be monuments of ignorance, prejudice, or ignoble jealousies, and the aim of all laws shall be the greatest good of the greatest number. One most important result has already been secured by the action of these congresses; in that, so far as the science of statistics is concerned, so far, we may even say, as the successful conduct of governmental administration is concerned, it has made the metric system of weights and measures a system of universal necessity, and rendered a familiar acquaintance with it absolutely indispensable to every statesman, every publicist, every teacher or student of political economy, and every enlightened lawgiver throughout the world.

It thus appears that there are powerful, permanent, and all-pervading influences steadily at work to advance the cause of metrological reform; and that these influences conspire to render the ultimate universal prevalence of the metric system of weights and measures nothing less than inevitable. It further appears that the actual progress which has been made in the extension of the system since the century began has by far exceeded anything which could have been reasonably anticipated, and has been sufficient to justify the most sanguine hopes for the future. When we consider, for example, that, at the close of the last century, the simple measure of length called the foot had not less than sixty different values still, probably many more, actually in use in different parts of Europe; and that, in 1867, at an Exposition in which the measures of all the world were all brought together, there could be found only eight of this discordant class still surviving; argument would seem to be needless in behalf of a cause which is so manifestly making its own way unaided. Whether our own people are to be participators in this grand movement,

which has already gone so far, is not with me a question of probabilities, but only a question of time. I expect very little to-day, and not much to-morrow; but beyond to-day and to-morrow there are many days coming, from which I expect everything. I know the strength of early associations and the power of rooted habits; I know how fondly men will hug the evil which is familiar and reject the good that is strange. I know that the Greenlander greatly prefers his icy mountains to the coral strands of India. My inference is, that we must look to a generation which shall not be so mentally one-sided as ours; a generation in whose training the good shall not be placed at so tremendous a disadvantage as it has been in our own; a generation which shall bring to this great metrological question a judgment at once fair, candid, unbiased, and unwarped by prejudices which mislead and bewilder us; to pronounce the impartial decision for which it may possibly appear that we are disqualified ourselves. And such a generation, gentlemen, permit me to predict, will yet be born upon the American continent, if it is not born already.

MACHINE MINING IN THE ST. LOUIS COAL REGIONS.

BY PROF. H. A. WHEELER.

MINING coal with machines has been carried on in the English coal-fields, where they were first introduced, for nearly three decades; yet the results are not very encouraging where economy is the main consideration. Several machines working on quite different principles have been tried, using rotary cutter bars, endless chains armed with cutters, swinging-picks, thrust picks, and the circular saw type; and some of these have been developed into highly efficient, practical machines when speed and capacity only are considered. But the heavy repair and other expenses incident to extensive compressed air plants, when competing against low rates of labor, have proved them to be more valuable for their moral effect than as expense reducers; so that while many plants that are suitable for machines are equipped with them, it is more for their high value in times of labor troubles and strikes, when the output of the mine is less dependent on experienced miners.

Under ordinary conditions, what difference there may be between the two systems in the cost of mining is apt to be in favor of the hand method, which is especially more marked in dull seasons, when labor is low; but with brisk trade and high wages, and especially during lockouts and other labor troubles, the machine plant will then have a pecuniary advantage.

The early experience with machines in the Illinois coal region tributary to the St. Louis market has been quite similar to the English practice; but such improvements have been made since their advent, that to-day the machines will generally do the work cheaper under ordinary trade conditions. Previous to the introduction of machines the St. Louis coal district was severely annoyed by the frequency of strikes, which occurred almost semi-annually. For with the brisk fall trade came the demands of the miners for higher rates, which usually resulted in a strike, until the operators would be compelled to grant the increase; while in the spring the operators would take advantage of the dull season to lower the rates, this resulting in another strike, in which the miners would usually succumb after a short lockout.

As the Illinois coals are all bituminous, and the principal one that supplies the St. Louis market soon deteriorates by weathering, it is the practice of the coal trade to deliver the coal immediately after mining, so that no stocks are carried in yards or stock-piles; in fact, the hand-to-mouth policy of the coal trade is carried so far that a few days stoppage of the coal-cars, during the great railroad strike of 1886, resulted in quite a serious coal famine, causing the price to jump from 10c. to 40c. a bushel (retail trade).

In order to be able to fill the steady daily demand of manufacturers, with whom close annual contracts are made, the coal operators were compelled to introduce machines, immaterial as to their economy, to tide over the strikes, and especially to reduce their dependence on the experienced miners. The principal machine used is so simple, that there has been no difficulty in hiring common laborers and getting fair results from them after a few days' work.

Having gone to the expense of introducing the machine plants, it has been a strong incentive to the operators to try to reduce the cost of operating them, though at first the machines would be abandoned in favor of hand-mining, at least during the summer season, when wages were low, as a matter of economy. But the capacity of the machines has been so increased, and the repair ac-

count so lessened by improving the machines, that the machine-plants are now run with a satisfactory saving on hand-mining. While it requires an extra cash outlay of $15,000 to $20,000 to equip a 400-ton mine with machines, in addition to their more economical work, the ventilation is assisted to the extent of from 4000 to 15,000 cubic feet of fresh cool air per hour from each machine (depending on the type used), while a new mine can be opened up quicker, and its subsequent output maintained with less development.* The machine-run mine will usually require a force of 8 men to each machine to put the coal on the mine-car, while 12 men would be needed for an equal output in hand-mining; but the latter are all skilled miners, while of the former only 3 are skilled or experienced men, the rest being common laborers, which will be no unimportant matter in times of strikes.

The principal portion of the St. Louis coal supply is mined within a radius of 60 miles from the "Belleville," or seam No. 6 of the Illinois coal series. This seam outcrops in the river bluffs of the Mississippi directly opposite St. Louis, and gently dips toward the northeast, requiring increasing depths of shafts to reach it, though the deepest is less than 600 feet. The mines that supply the St. Louis market, being close to the western edge of the basin, have only to hoist from a depth of 100 to 300 feet. This seam furnishes a bituminous coal that varies somewhat in quality at the different mines, though generally it is rather high in sulphur and ash. It is a fair steam and domestic coal, and from its close proximity and favorable conditions for cheap mining, it can be placed in the St. Louis market at such a low figure† as to keep out, for general use, the superior coals of the Indiana, Ohio and Pittsburg regions.

It is underlaid by fire-clay, and usually has a fair to strong roof of "slate" or limestone, while it is exceptionally free from faults and water. Its average thickness is between 6 and 7 feet, rarely as low as 5 feet, and occasionally as much as 8 or 9 feet. It has a few very gentle rolls or undulations that are so slight as to rarely cause any annoyance about water or tramming, while thus far there has been no serious occurrence of fire-damp. It is a remarkably easy seam to work, being of such an economical thickness, nearly

* For an equal capacity a hand-mine will need about 20 per cent. more rooms, or "breast stopes," than a machine-mine.

† Wholesale rates are from $1.25 to $1.75 per ton in East St. Louis, and about 50c. per ton higher, after transferring across the bridge, on the city switches.

level, dry, free from faults, with well-defined "cleat" and "cline," while the fire-clay floor admits of easy undercutting. The conditions are most favorable for machines, especially as the rooms can be carried as wide as 45 feet in many of the mines, where the roof is a firm limestone.

Another Illinois coal that is meeting with favor in the St. Louis market comes from the Big Muddy and Carbondale districts in Southern Illinois, some 100 miles distant. This is a superior coal to the "Belleville," but the longer haul prevents it from competing in price with the latter, whose mean haul is only about 25 miles. Although machines have been introduced in these southern mines, the figures herewith given are drawn from the mining practice in the "Belleville" seam as worked in the immediate proximity of St. Louis.

There are about 120 mines in Southwestern Illinois that ship more or less of their product, aggregating about 3,500,000 tons per annum, to the St. Louis market. While only about 25 per cent. of this number mine with machines, yet as these include all the large producers, at least two-thirds of the output is produced from the machine-equipped mines. The other 75 per cent. are mostly small mines that are operated mainly for local consumption, and so are not active competitors in the St. Louis shipping trade. Many of these small operators have not the financial ability to equip their mines with a machine-plant, while most of them are not worked on a large enough scale, or with sufficient regularity, to obtain any economy with machines. For a hand-mine can shut down during the dull season without any appreciable expense, if kept unwatered, while a machine-plant deteriorates much more by idleness than when running, while the interest and investment charges go on continuously, and with hand-mining rates ranging between 37½c. to 62½c. a ton, there will be no saving in small machine-plants under such disadvantages. The "Belleville" seam is generally worked by undercutting, and then throwing down the coal with black powder, as it is "too strong" to be wedged down. In working-rooms about 40 feet wide, and undermining for a depth of 3½ to 4 feet across the full width of the room, it will usually take about 6 holes to blast down the 40 feet face, using about a pound to the hole, and firing with squibs.

Sometimes the coal is so tender as to render shearing necessary, to prevent making too much slack, while in a few mines the coal

is so strong as to be shot from the solid without undercutting, though done with the production of an excessive amount of slack.

The mines are all operated on the room and entry system of mining, the old and small mines being opened on the single entry plan, while the large and more recent mines are being worked by double-entries, and in two instances by triple-entries. The hand-mining is all done by contract at rates that vary from 1½c. to 2½c.* a bushel, according to the local and trade conditions. Before the introduction of machines the fluctuations were more extreme, going as low as 1c., and as high as 4 and 5c. Two miners work together in one room, and undercut, blast, load, and timber the room for an average price of 2c. a bushel, or 50c. a ton, for lump coal, as screened over ⅞″ to 1¼″ screens, and will average 100 bushels, or 4 tons per day per man.

The miner pays for his own powder, oil, tools, blacksmithing, etc., so that the above mining rate will pay the complete cost of putting the clean lump coal on the mine-car. Tramming, hoisting, pumping, development, general maintenance, and superintendence will amount to about 1c. a bushel more, so that 3c. a bushel, or 75c. a ton,† will generally include the entire cost of putting the coal on the railroad-car at the mouth of the pit, at the present rather low rates.

In machine-mining, each machine is in charge of two men who simply undercut the coal, passing from room to room as the undercutting is finished. A blaster follows the machine, who does the drilling and shooting, while the loading is done by laborers in gangs of two each, who follow after the blaster; a timberman precedes the machine, who secures the roof and attends to any necessary track-laying. So, while the machine is undercutting in one room, the blaster is drilling and blasting in the room that has just been undercut, while the coal is being picked over and loaded, and the room cleaned up by the loaders in the preceding rooms. Hence it is necessary to have five rooms to each machine, to prevent any delays and keep the machine-runners constantly at work.

There are three different machines in use in the St. Louis coal

* A bushel is reckoned as 80 lbs., or 25 to a ton; recently the St. Louis coal trade abandoned the antiquated bushel system of weights, and adopted the ton of 2000 lbs. as the standard.

† Where the coal is mined on royalty ¼c. to ½c. a bushel more should be added to this figure, ¼c. being the usual price of the land-owners.

region, that operate on two different principles. The Legg mining-machine is a rotary cutter, in which a horizontal bar, armed with detachable knives at the end of a movable frame, is fed forward under the coal by a duplex engine. The Harrison and the Yoch machines are simply percussion drills, or straight-moving power picks, in which a broad pick-bit, secured to the end of the piston-rod of a small engine mounted on wheels, chips or picks away the coal or fire-clay. The Legg machine was originally placed on the market under the name of the Lechner Coal-Mining Machine in 1876, and is now made, after being improved by Mr. B. A. Legg, by the Lechner Mfg. Co., of Columbus, Ohio. From the front view of the Legg machine, as given on page 305, the cutter-bar is seen to be armed with small steel knives that are so set in a spiral along the horizontal bar as to make a continuous semi-cylindrical cut in one revolution. The shanks of these knives are held in their slotted seats by set screws, and need to be replaced by a sharp set about once every hour, when cutting continuously. The central link-belt carries the power from the 5″ x 5″ duplex engine (after gearing down 4 to 1 to reduce the speed), while the small link-belts behind the cutter-bar, that are studded with short projections, push back the cuttings from the cutter-bar and so keep the undercut free and open for the advance of the machine. The

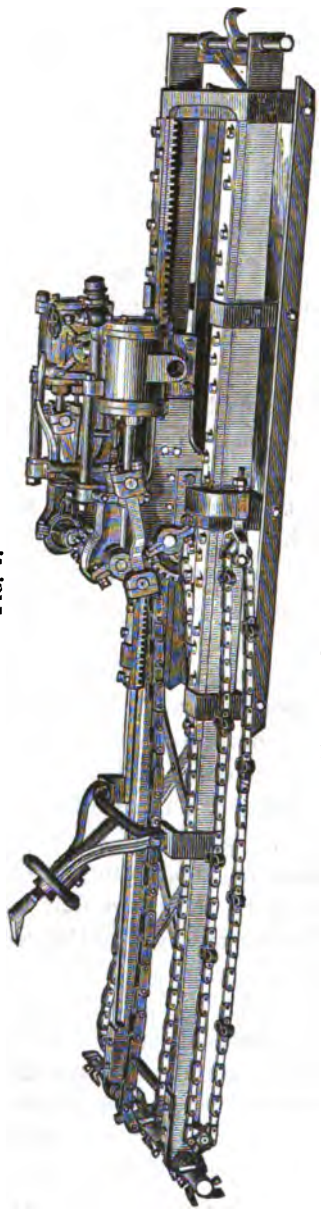
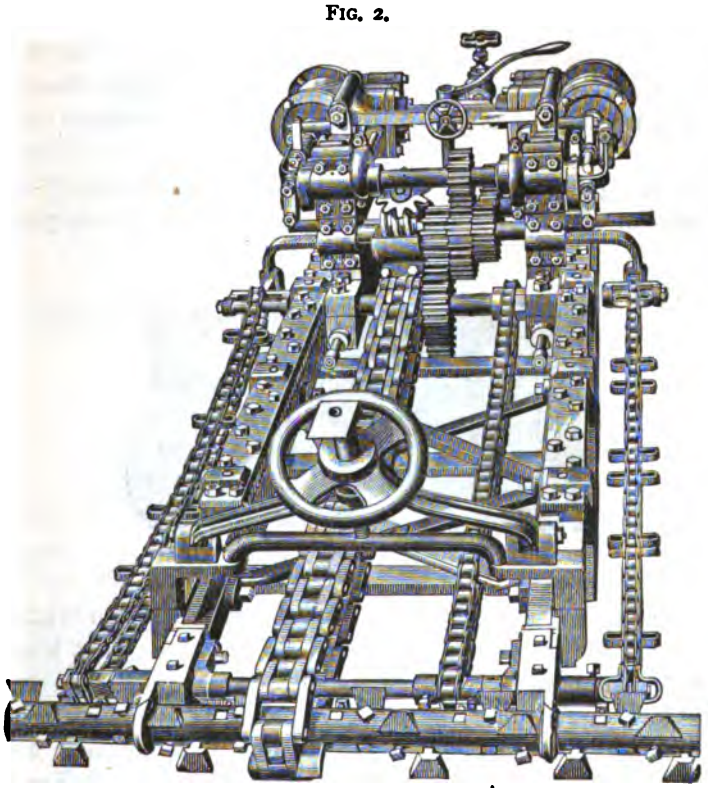


FIG. 1. Side View of the Legg Coal-Cutter.

engines are attached to the cutter-bar frame, which is racked forward and back on the bed-plate, the latter being temporarily held firm by dogs to the floor and face of the coal while the cut is being made. As the frame can be racked forward 5 feet, while the cutter-bar is usually made 3 feet long, 15 square feet of the coal may be undercut from one position of the bed-plate, though 13½ feet is generally as much as is accomplished in practice; the thickness of

FIG. 2.



Front View of the Legg Coal-Cutter.

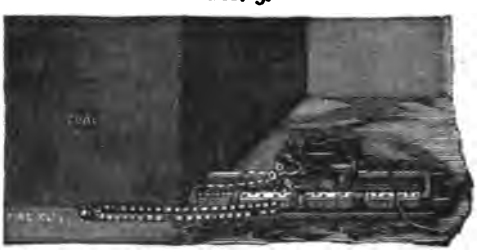
the cut is about 5 inches. The bed-plate has to be shifted along the face of the coal with pry bars, as the cuts are successively completed, by the two runners, and the machine is transferred from room to room on a special flat car. The speed of cutting will naturally vary with the character of the coal, as a dirty coal, especially if charged with pyrite, not only impedes the progress but rapidly dulls the knives, occasioning frequent delays in chang-

ing them. With a clean coal, and the machine in good order, a single cut will take about 8 minutes; 2 to 5 minutes are needed to shift the bed-plate for the next cut, while about 10 minutes are required to change the dull knives. Allowing for these and other incidental delays, a machine will make from 25 to 40 cuts, or 75 to 120 lineal feet of undercutting per shift of 10 hours; a month's average, varying from 40 to 108 feet, was 75½ lineal feet, equal to 377½ square feet a shift.

The consumption of compressed air, at 60 lbs. pressure by the driving engines, is from 40 to 60 cubic feet per minute. The weight of the machine is about 1200 lbs., and the cost for the three-feet machine is from $1200 to $1500, according to the territory applied for.

The Legg is a most excellent machine for rapid cutting, while the amount of coal lost in the undercut is very small, being much

FIG. 3.



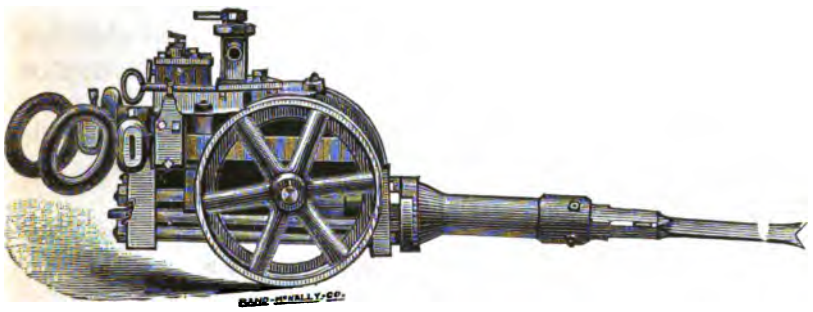
The Legg Machine at Work.

less than in hand mining, or with the Yoch or Harrison machines. With coal free from pyrite concretions ("sulphur balls"), and if the machine could be readily maintained in good order, an undercut of 500 square feet would not be a high average with experienced miners. But the vulnerable features of the machine are its high first cost and extremely expensive maintenance. For with so much chain-belting and gearing, running at high speeds and exposed to the most trying of conditions of dirt and dust, the wear and tear is excessive, and the frequency of consequent delays very aggravating. This makes the life of a machine so short, in spite of frequent renewals, that it has been almost completely abandoned in this district.

The Yoch machine is so similar in its design and action to the Harrison, the only difference being in small mechanical details in

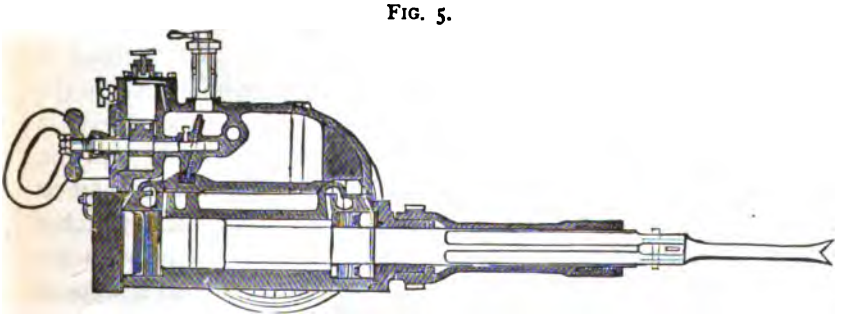
carrying out the same principle, that a description of the latter will suffice to explain the character of the former. The Harrison machine is made by G. D. Whitcomb, Chicago, Illinois, and is shown in perspective and a longitudinal section below, while the method of working the machine is shown on page 309. It consists of a plain slide-valve 4″ x 10″ engine (the ports being at each end of the cylinder), in which the long B valve is actuated through a nut by a spiral disk-wheel on the shaft of a small rotary engine.

FIG. 4.



Side View of the Harrison Coal-Cutter.

FIG. 5.



Longitudinal Section of the Harrison Coal-Cutter.

This rotary engine for operating the main valve is placed at the back end of the steam chest, and by means of the fly-wheel on the outer end of its shaft can be started at any position. A special throttle-valve permits this rotary engine to be run at any speed, and so allows of regulating the rapidity of throw of the B valve, and hence the speed and length of stroke of the main piston.

The outer end of the piston-rod is square in section, and passes through a bushed, rigid guide-sleeve that relieves the stuffing-box

of side thrust as the pick strikes the coal, and prevents it from rotating. The machine is worked on a 3′ x 8′ platform, that is so "pitched" in front of the coal (at an angle of about 5 degrees) that the recoil or "kick-back" from the blows will be about neutralized by gravity. The machine is hung by means of trunnions between a pair of light-carrying wheels that allow great freedom in the poise and movement of the machine while at work. As the machine picks its way under the coal at the rate of 200 to 220 blows per minute, the runner allows it to run down forward on the platform, bracing the wheels with his feet, and swings the pick from side to side as it progresses, by means of the adjustable handles. A helper shovels away the débris as it accumulates, using a special, long-handled, flat shovel. When the machine has completed the cut, which will vary from 3 to 4½ feet in width (according to the skill of the operator), the platform is shifted along the face of the coal, and a new section is undermined.

It takes about 6 minutes to shift the plank, about 1½ minutes to change the bits, and about 16 minutes to make a cut 4 feet wide by 4 feet deep. To disconnect, load up the outfit on a car, tram to the next room, unload, and start at work again takes about 20 minutes. The total time lost by these delays will amount to from 2 to 2½ hours in a ten hour shift, so that the machine will be in actual operation 75 to 80 per cent. of the time. The cutting is generally made partly in the underlying fire-clay, and partly in the coal; if the fire-clay is highly indurated the cut is made entirely in the coal, as it works so much easier. The shape of the finished cut, shown on the adjoining page, is a truncated wedge that is about 12 inches high at the brow or face of the coal, and about 3 inches high at the back of the cut. A skilful operator can so work his machine as to recover about ⅓ of the volume of this wedge as lump coal, while the balance will be reduced to "slack," which is thrown back in the gob, and so lost. This leaves the undercut coal in good shape for blasting, as on now being thrown down by the powder, the blocks will roll over and be free for attack by the loaders with their wedges. In the Legg machine, the cut is so small (less than 5 inches high) that the coal is still inaccessible for loading after proper blasting (with a minimum of powder), so that the brow of the cut along the face has to be worked off with a pick, to allow the block of coal to roll over free and loose, and not get jammed against the roof. The cutting capacity is found to be be-

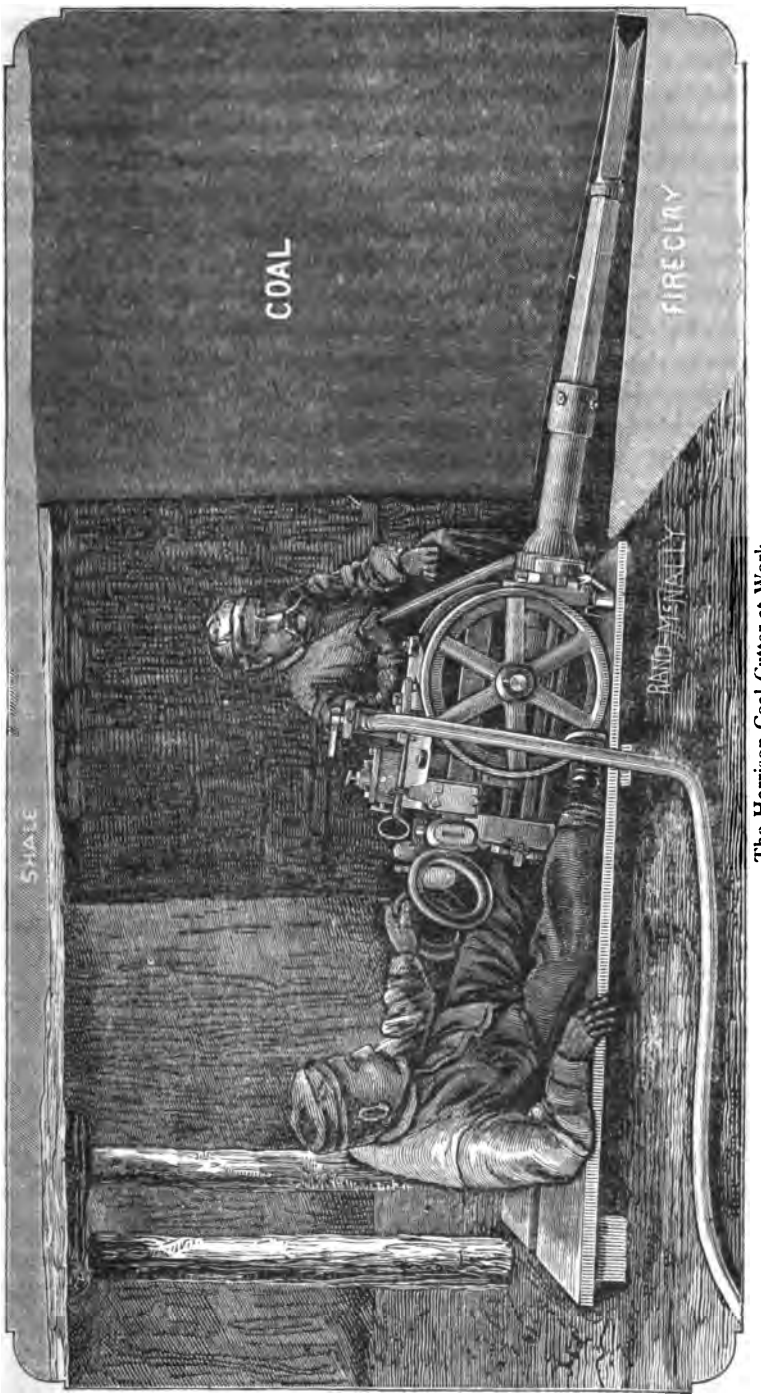


FIG. 6.

The Harrison Coal-Cutter at Work.

tween 60 and 70 lineal feet per ten-hour shift, with the air-pressure at 80 lbs.; the average for six machines for a month was 63.8 feet, which is a fair figure for ordinary machine runners; old expert runners can steadily cut from 70 to 80 lineal feet, and on competitive trials and test runs have cut as high as 100 to 130 lineal feet.

The depth of the cut can be readily maintained at 4 feet, though in the "Belleville" district it will be found to more frequently measure only 3½ to 3¾ feet; the average work of a machine can be placed at 230 square feet, or 40 per cent. less than with the Legg machine. If the machine-runners were paid for the square feet actually cut, and if the mines were run with sufficient regularity to keep good men, there would be no difficulty in averaging at least 70 lineal feet of 4 feet depth of cut, or 280 square feet per day, while 300 square feet would not be an excessive estimate. What few efforts that have been made to pay the runners by contract has shown a marked improvement in the cutting, the machines averaging over 280 square feet; and when the machines have become more firmly established, this will undoubtedly be more generally adopted, as securing the full depth of cut and the maximum work out of the machine. Where the cutting was thus let on contract, ½c. a bushel, or 12½c. a ton was paid to the runner and helper, and in another case 4c. to the runner and 3c. to the helper for each lineal foot of 4 feet depth of cutting; in both cases the miners accomplished more work, and made larger wages than at present with their daily system of wages.

The consumption of air is stated to be 10 cubic feet at 70 lbs. pressure per minute, though 15 feet would be a safer figure, with leakages, etc., to contend with. The Norwalk Compound Compressor is in quite general use, and 80 lbs. is the usual pressure maintained at the compressor. In addition to a large air-receiver on the surface, each machine has a small receiver, about 1½′ x 6′ in size, supplied by a 1½-inch pipe from the main air-pipe.

The weight of the "Heavy Standard" Harrison machine is about 700 pounds, and costs $300, exclusive of the $300 additional that is charged as royalty for the right of use in stipulated districts. The "Heavy Standard" machine is the size in general use, and for which the data given in this paper apply; a modified type, called the "Light Standard," weighing only 500 pounds is made, that is especially adapted for shearing and entry driving, as it is capable of undercutting to a depth of five feet. As the "Heavy Standard" pattern

has only been in use since 1882* it is too early to attempt to give an average value for the life of a machine; but as many of the first machines are still doing good service, it seems probable that it can be taken as at least seven years. While the usual practice is to have one extra machine for every three or four in use, to keep the full complement at work during repairs, very few of the mines having a machine shop, and hence being obliged to send abroad to make repairs, a large plant, equipped with a machine shop capable of making its own repairs, would probably find a 15 per cent. reserve ample to keep the working complement in continuous operation. The vulnerable features of the Harrison machine that need frequent renewals are: the brass bushing that guides the piston rod at the end of the sleeve, which lasts about 3 months; the leather cushions at each end of the cylinder, for cushioning the piston, which lasts 5 or 6 months; the piston-rod packing crimps, lasting about 2 months; the rotary-engine valve lasts about a year, while the rotary piston lasts about two years. The picks are 14 to 16 inches long when new, and need resteeling in 4 to 6 months, by which time they are worn down to about 6 inches in length. The sleeve and piston-rod are occasionally broken, having a mean life of about 30 months.

The Yoch machine,† which was invented in 1881, has a cylinder 6″ in diameter, with an average stroke of 14 inches, and, in the later machines, takes a cut 4 feet deep; the earlier machines made a 5-foot cut, but this was found to be too severe on the piston-rod. The main valve is worked by a little independent crank and fly-wheel engine, situated in the air-chest, while the piston cushions on air and so saves the renewal of the leather cushions used in the Harrison machine. The machine is hung on two pivoted columns that are mounted on a 4-wheel truck, which latter runs on a pair of rails that are slid along the face of the coal as the cutting proceeds. On account of the large size of the cylinder, the machine strikes such a heavy blow that the coal is crushed to slack, and no lumps are recovered from the undercut, as with the Harrison machine.

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* The first Harrison machine patent dates December 25th, 1877.

† For an illustrative description of the Yoch machine, see the "Iron Age," March 22d, 1888.

The capacity is about 70 lineal feet of 4 feet in depth, or 280 square feet in a 10-hour shift. While the machine is a more powerful cutter, and should perform considerably more than its prototype, the Harrison machine, it is so much heavier and less readily handled that but little more work is actually accomplished. It consumes more than twice as much air, and is more expensive in repairs than the Harrison, while the first cost is the same; hence it is not suprising that it has not been more generally introduced, as it has been used only at a few mines, and is even being driven out of these by the Harrison machine. The machine is made at Belleville, Ill., by the Yoch Mining Machine Manufacturing Co.

An estimate of the cost of mining with the Harrison machine ("Heavy Standard" pattern) for a plant of about 400 tons daily capacity, which is about the usual size of the shipping mines in the Belleville district, is herewith given. In making up such an estimate as this, of course only general figures can be given, that will have an average value; local conditions will more or less modify these for any particular plant, while different seasons will cause considerable fluctuations in the principal daily expense, the labor item. Attention is respectfully called to one item of cost that is so very frequently omitted in engineers' estimates, to wit: the pro-rata that must be charged each year to return, as a sinking fund, the capital invested in the complete original outlay, besides the annual outlay in repairs that is required to keep this first investment in use. For not only must interest be charged against this cash investment (whether purchased through loans, mortgage, or out of the cash capital), but the principal must be returned by the time the plant is worn out, which, in this case, is assumed to be at the expiration of ten years, except the machines, whose mean length of service is put at six years. The plant investment required to maintain such an output, for which 8 machines will be necessary, is assumed to be as follows:

Plant-Investment for an 8-Machine Mine.

Compressor: 1 Compound Norwalk, 20″ × 24″ steam cylinder, ...		$3000
Erection and *housing* of compressor, ...		1500
Air-receivers: 1 main receiver 4½′ × 12′, . .	$ 330	
8 entry receivers, 1½′ × 6′ @ $90,	720	
		1050

Piping: 500 feet 5″ shaft piping @ 54 cents, .	$270	
2000 feet 3″ main-entry piping @ 28 cents, ...	560	
10,000 feet 2″ cross-entry piping @ 13 cents, ...	1300	
5000 feet 1½″ room-piping @ 10½ cents, ...	525	
Total, ...	$2655	
Erection, ...	885	
		$3540
Boilers: Two 50 horse-power boilers with complete fittings, ...		2000
Erection and *housing* of boilers, ...		1000
*10 *Harrison Mining Machines*, "Heavy Standard," including royalty, @ $600, . .		6000
Hose: 8 pieces, 4-ply, rubber hose, 50 feet long, with couplings, @ $40, ...		320
Extra picks (8 @ $3), *Tools*, etc., . . .		300
Freight, Incidentals, etc., ...		1290
Total, ...		$20,000

On this basis of an investment of $20,000, which would be required to convert a hand mine into a machine mine (independent of all outlays for hoisting, pumping, ventilating, and other machinery for general maintenance), the following estimate is made for the complete daily expenses of running a Harrison machine.

Running Expenses of a Machine per Day, with an 8*-Machine Plant and* 300 *Working days per Year.*

		Cos	Percentage of the whole.
Labor:			
1 machine runner, ...	@ $2 25		
1 machine helper, ...	@ 2 00		
1 blaster, ...	@ 2 25		
1 timberman, ...	@ 2 00		
4 loaders, @ $1 75, ...	7 00		
		$15 50	77.6
Blacksmithing:			
8 machine picks, @ 4 cents, . . .	$0 32		
8 drill-augers, @ 1½ cents, . . .	0 12		
		0 44	2.2
Supplies;			
Powder, 10 pounds, @ 10 cents,† . .	$1 00		
Oil and packing, ...	0 10		
		1 10	5.5

* 8 for use, 2 as "extras" during repairs.

† Including squibs and paper.

Repairs:			
On machine, daily pro rata, $\left(\frac{\$60\ 00}{300\ days}\right)$.	$0 20		
Hose and piping, pro rata, $\left(\frac{\$60\ 00}{300\ days}\right)$.	0 20		
	——	$0 40	2.0
Compressor:			
1 engineer, ...	2 25		
½ fireman, ...	0 88		
6 tons slack coal, @ 15 cents, . .	0 90		
Repairs and supplies to compressor, .	1 00		
Repairs and supplies to boilers, . .	0 50		
Total for the 8 machines, .	5 50		
Expense for 1 machine, . .	$\left(\frac{\$5\ 50}{8}\right)$	0 69	3.5
Interest on $20,000, @ 10 per cent. per machine for $\frac{1}{100}$th year, . . .		0 84	0.2
Sinking Fund:			
$14,000, @ ten years per machine, for $\frac{1}{100}$th year, ...	0 58		
$6000, @ six years per machine for $\frac{1}{100}$th year, ...	0 42	1 00	5.0
		$19 97	100.00

On a tonnage of 50 tons per day per machine, this total expense of $19.97 gives a rate of 39.$\frac{94}{100}$ths cents, or, say 40 cents per ton for undercutting, blasting, and the labor of timbering, and loading the coal on the mine cars, as against 50 cents a ton when this same work is done by hand miners. Where the seam is thin, or the coal poor in quality, less coal will be obtained from each machine, and as the expenses will remain about the same, it will make the rate higher; thus, on rooms that produce only 45 tons per day per machine, the rate per ton will be 44½ cents.

The estimate is based on a year of 300 working days, which is the minimum that a mine should be worked to produce economically; but as the average working-year for the coal-mines of Illinois* in 1886 was 206 days, the cost of machine mining, when revised on a basis of 200 days of work for the whole year (to allow for shutting down during the dull season) is at the rate of 43$\frac{64}{100}$ths cents on the 50-ton basis, and 48½ cents on the 45-ton basis, as the total daily expense is raised to $21.82. The sinking-fund charge is 5 per cent., and the interest is 4.2 per cent. of the total daily expenses on the 300-day basis; but the former is increased

* Annual Labor Report, 1887. Springfield, Ill.

to 7 per cent., and the latter to 5.7 per cent., when the plant only works 200 days in the year.

A popular figure for the cost of a Harrison machine per day for power, repairs, interest, and depreciation is put at $2.50, or 5 cents to 5.7 cents a ton. This is too low, as will be seen from the estimate ($2.93), though large plants, working full time, and having the cutting done by contract, could probably work very close to the 5-cent rate.

TOWN'S TRUSS.

BY PROFESSOR W. P. TROWBRIDGE.

In a paper read before the New York Academy of Sciences during the last year, on the history of the art of bridge construction, I took occasion to refer to the truss invented by Ithiel Town as the first example of the introduction of the mode of construction of long-braced girders, in which straight top and bottom chords are connected by diagonal bracing.

In that paper, however, I could not, for want of time, enter into any notice of Town's invention, beyond the general statement that the truss known by his name was the first example in history of this mode of construction, and that the bridge near New Haven, built by him in 1823, is therefore probably the oldest bridge now in existence constructed on this principle, and possibly the oldest wooden bridge of equal span to this now standing.

In Weale's work on bridges, published in London in 1843, Town's truss is fully described, both in the plates and in the text, under the title, "American Timber Bridge," and the following quotations from that work referring to Town's bridges are interesting.

In describing this truss the author says: "Each truss consists of a series of diagonal or truss braces inclined at an angle, somewhat steeper than 45°, crossed by another series inclined at the same angle in an opposite direction, and of a horizontal string-piece at top and bottom; the whole firmly secured by wooden tree-nails of hard wood. * * * * We are not aware of any situation in this country or in Europe, where a bridge on Mr. Town's

principle has been erected. In America, however, there are many of these bridges on a scale truly gigantic."

The most important examples then existing in this country were said to be as follows:

"The bridge built by the celebrated engineer, Moncure Robinson, for carrying the Richmond and Petersburg Railway across the falls of the James River at Richmond. The length of this bridge is 2900 feet, and the trusses are supported on 18 granite piers. The distances between the piers vary from 130 to 150 feet." In addition to this great work on Mr. Town's principle executed by Mr. Moncure Robinson, may be mentioned another on the same principle across the Susquehanna, 2200 feet in length, with spans of 200 feet, one at Nashua, New Hampshire, one at Newburyport, Mass., another at Northampton, Mass., one at Providence, R. I., one near Philadelphia, one across the Delaware near Trenton, one on the Harlem Railway near New York, "four across the Hudson and Mohawk rivers near Troy, one over the Schuylkill, for the Baltimore Railway, two on the Petersburg and Raleigh Railway, one in Canada, one in Alabama, and another in Ohio."

The author of the paper in Weale's work, from which these extracts are taken, then states the advantages of the system, substantially as follows:

1. "Spans of 300 feet may be constructed of common planks not exceeding 30 feet in length."

2. "There is no lateral pressure or thrust against the piers or abutments."

3. "The bridge has a degree of stiffness and freedom from both vertical and lateral motion superior to most other works, whether in iron or wood, and this advantage is possessed in connection with the practicability of always securing a perfectly horizontal roadway."

4. "These bridges are put together in America with remarkable rapidity, as an instance of which may be mentioned a bridge on the railway from Philadelphia to Norristown, which consists of three openings of about 190 feet each. The construction of the bridge at a height of 78 feet above the bed of the river, occupied no more than ten weeks."

In the *Dictionnaire des Arts et Manufactures*, of Laboulye (Paris, 1867) occurs the following: "The bridges thrown over American rivers attain dimensions of which we find no examples

in France. . . . Almost universally they present the character of boldness and economy, which American constructors know so well how to stamp upon their works. We shall examine here only the ingenious arrangement of lattice bridges of Mr. Ithiel Town, which, under the name of '*ponts Americains*,' is the only American bridge generally known in France. This quite new combination in *bois de charpente* offers in many cases incontestable advantages."

The above quotations are sufficient evidence that Town's invention was not only novel, but that it was in the highest degree practical. Wrought iron had not come into use in bridge building, except in the form of the chain or wire suspension system, and cast-iron, first employed in England about the year 1777, was confined to the arch form.

The characteristic feature of the new invention consisted in employing straight top and bottom chords, united by diagonal bracing. No piece of timber was subjected to a cross strain, and the abutments were not subjected to lateral thrust.

The principle thus introduced for timber bridges not only required no modification when wrought iron took the place of timber, but rather rendered the use of iron and steel possible, as these materials are almost universally employed at the present day in bridge building.

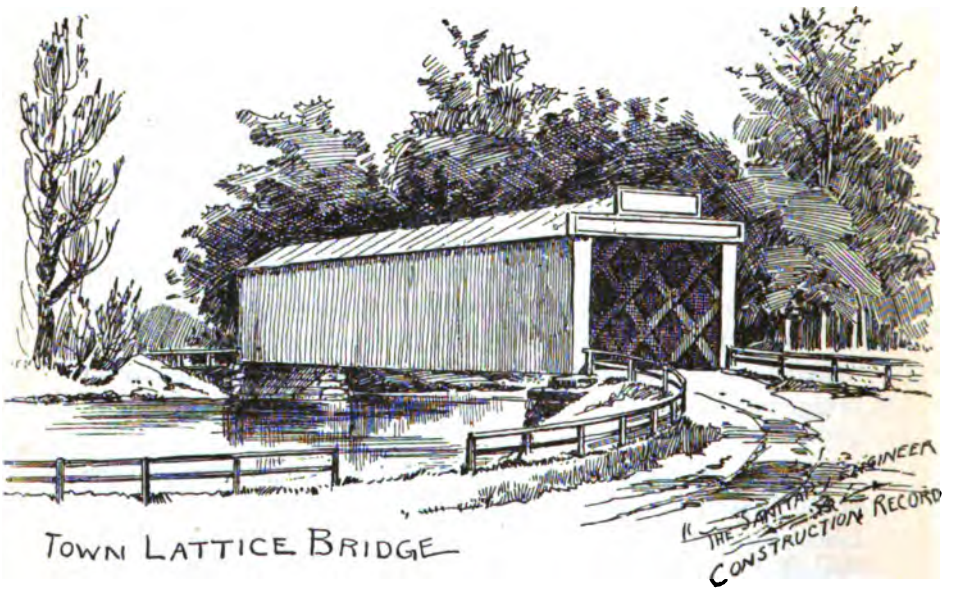
The railroad bridge now occupies a place in connection with the economy and facilities of land transportation, second in importance only to that of the steam engine itself, and, considering the extended use in so important a cause, of the type of truss here described, it seems but proper that the name of its originator should be preserved in the list of those whose inventions have proved of great and enduring public benefit.

The question of priority in regard to the invention of the braced-girder has perhaps been a doubtful one. This arises, I think, from the fact that no systematic investigation of the matter appears to have been undertaken.

There is no difficulty in giving the time when Town erected his first bridge near New Haven. Fortunately this bridge is still standing, and is represented in the sketch accompanying this article. The length of the bridge is 100 feet, its breadth 14 feet, and its height to the top chords 12 feet. I am indebted to Mr. Eli Whitney, of New Haven, Conn., son of the inventor of the cotton

gin, and of the principle of "interchangeability of parts" in the manufacture of implements and machinery, for the history of this bridge, and it will be at once observed that there can be no doubt of the accuracy of his statements, since they are matters of his own personal knowledge.

Mr. Whitney states, that in the year 1823 or 1824 his father took him to see this bridge, which Mr. Town was then erecting over the Mill river near New Haven, for the "New Haven and Hartford Turnpike Co." About twenty years later, Mr. Whit-



ney became interested in the construction of the New Haven water works, and built the dam and reservoir on Mill river, for the storage of the water. It became necessary either to destroy Town's bridge, or to remove it to a point somewhat more than a quarter of a mile up the stream, where a bridge would be needed for crossing what would become a narrow part of the new reservoir.

Mr. Whitney decided to remove the bridge entire. A crib-work pier was built under the middle of the span, and by means of a horse-whim the bridge was drawn endwise upon dry land. It was then drawn by the same means on skids to the new site, where, by a process the reverse of the first operation, it was again

thrown across the stream. Here it has remained ever since, and is used daily, the main, and original chords and braces being in a comparatively sound condition, and remaining in place as they were built by Town in 1823.

The only other inventor whose name has been connected with that of Town in regard to the question of priority, was Col. Long, of the U. S. Engineers. General Barnard, in his article on bridges in Johnston's new Cyclopædia, states that Long constructed his first bridge in 1828, and other authorites place the time of the invention of Long's truss between 1828 and 1831, during which time Col. Long was employed as Chief-Engineer of the Baltimore and Ohio Railway.

The invention of Long followed that of Town by at least five years, and therefore to the latter, I think, should be awarded the honor of the invention.

THE APPRAISEMENT OF DAMAGES TO WATER-POWERS IN THE EXERCISE OF THE RIGHT OF EMINENT DOMAIN.*

BY WILLARD PARKER BUTLER.

THE appraisement of damages to water-powers arising when the waters of a stream are taken in the exercise of the right of eminent domain, has long been a topic of interest to both lawyers and engineers. There is probably no more interesting department of the law than that which treats of riparian rights, and there is also no form of legal proceeding in which, on the whole, so unsatisfactory results are reached, as in that form provided by the law of most of our States for the ascertainment of the amount of compensation to be awarded to owners whose property is taken for public uses. In the case of the appraisement of the damage caused by the taking of land, some adequate compensation to the party injured, can usually be arrived at, for the reason that the value of any tract of land is ascertainable with comparative ease.

* This article originated in the discussion of a paper of a similar title read by Professor W. P. Trowbridge before the New York Academy of Sciences, and published in the preceding number of the QUARTERLY.—EDS.

But in the case of the condemnation of water-rights, the mixed tribunals, such as are the commissions usually appointed for such purposes, are extremely apt to arrive at totally wrong and inadequate results, thereby causing gross miscarriages of justice, and inflicting great hardships. Commissions, except in rare instances, do not seem to be able to mete out substantial justice between the parties in such cases, and the awards given by juries in ordinary common law actions for damages by reason of the impairment or diminution of riparian rights, are, on the whole, very much more just and fair to the party whose property is taken than the awards given by commissions. The reason of this seems to lie in the better capacity of juries for determining the naked facts from the evidence, commissions being too apt to tamper with the facts, by the infusion of too much of what they are pleased to call their "discretion as intelligent men," and being far too prone to disregard the scientific testimony of the experts.

Now, the rule for the ascertainment of damages in cases of taking property in the exercise of the right of eminent domain is perfectly simple and clear, and in most of our States it has been defined over and over again. The object of a proceeding to appraise damages in any case of this sort, is not to effect restitution, nor to supply to the party whose property is taken some other equally good property, which will possess similar possibilities, but simply and solely to award to the party injured a sum of money, which will fully indemnify him for all the loss that he has suffered. When a legal wrong has been committed, and a suit is brought to recover damages for such wrong, the measure of damages is such a sum as will, so far as possible, make good to the party injured the damage he has sustained by the injury, or will, so far as possible, *make him whole, or put him in the same condition as he would have been in if the injury had not occurred.* But the law does not contemplate supplying the party whose property is taken, with *the same* thing that has been taken, or a similar thing. However, the party injured by the taking is to be allowed precisely the same measure of damages as if the taking were an ordinary legal wrong, which would clearly be the case were it not for the existence of some authority, under which the taking is made lawful, and in most cases, I believe, in which the right of eminent domain is exercised, the exercise of the right is made lawful by some sort of legislative authority.

This wholesome principle of *full indemnity* has been engrafted upon the law of most of our States,* but is, unfortunately, seldom or never applied by commissioners in their deliberations. This is another reason why jury awards are uniformly more satisfactory, for in such cases the juries determine the facts from the evidence, and the court is bound to instruct solely upon the principles of the law.

In ascertaining the damage in the case of a water-power which has been diverted, there are really only four things to be determined, namely, the following:

1. The amount of water-power which the stream afforded the owner prior to the diversion.

2. The amount of water-power which the stream affords the owner subsequent to the diversion.

3. The market value of the water-power which the stream afforded prior to the diversion.

4. The market value of the water-power which the stream affords after the diversion.

The first two of these matters are strictly questions for the scientific experts. The latter two belong more properly to the province of the real estate broker, subject, of course, to the expert's opinion as to the first two, and to his aid and assistance. Now, the market-value of property which is taken under the law in the exercise of the right of eminent domain, must be the fair commercial value of the property for that purpose for which it is most valuable. The water is a part of the inheritance and passes with it. Hence, the market-value of a particular water-power may become enhanced above that of other similar powers generally, by reason of the fact that the water used in producing the power may be more valuable for some other purpose in connection with the estate of which it forms a part. Hence, the value of the water to the adjacent lands before and after taking, for any and all purposes for which it may be used, must be determined before its actual market-value can be fixed. The value of the water for such purposes is naturally very often

* Grand Rapids R.R. *v.* Heisel, 47 Michigan Reports, 393; Kilbourne *v.* Suffolk, 120 Massachusetts Reports, p. 393; Jones *v.* Chicago, etc., R.R. Co., 68 Illinois Reports, p. 380; Bangor, etc., R.R. Co. *v.* McComb, 60 Maine Reports, p. 290; San Francisco, etc., R.R. Co. *v.* Caldwell, 31 California Reports, p. 374; Livermore *v.* Jamaica, 23 Vermont Reports, p 361; Young *v* Harrison, 17 Georgia Reports, p. 30; Root's Case, 77 Pennsylvania State Reports, p. 276.

unknown to the expert, and can only be determined by reference to sales taking place in the same neighborhood. The courts, however, have invariably applied this rule,* and it ought not to be disregarded.

This being clear, the general rule for the determination of damages in cases where property is taken in the exercise of the right of eminent domain, is easily intelligible. This rule is defined as follows: *The difference between market-value of the property before the diversion, and the market-value of the property after the diversion is the damage which the person whose property is taken, has suffered.*†

The application of the rule of *full indemnity* requires that any doubt existing in regard to any scientific fact, or as to the applicability of any existing standard of value in the mind of an expert, should be resolved in favor of the party whose property is taken, and not in favor of the person or persons who take the property. It also requires that each element entering into the calculations of experts should be fixed at a figure sufficiently large to give the party whose property is taken the benefit of more than the average conditions.

Where experts make calculations to determine what the flow of a given stream is, in order to supply a certain town with a given amount of water, motives of prudence and safety require them to assume a minimum for each element that enters into their calculations. In computing water-supply, water-powers, and values of water-powers in cases where water is diverted, the application of this legal principle requires that the questions arising should be looked at in a totally different and very much broader light. That is to say, while a *maximum* ought not to be assumed for each element, the rule of *full indemnity* requires that a fair mean average should

* In New York see Trustees of College Point *v.* Dennett, 2 Hun's Reports, p. 669; Henderson *v.* N. Y. C. R.R. Co., 78 New York Reports, p. 423. In the matter of the N. Y. C. & H. R.R. Co., 6 Hun's Reports, p. 169. In the matter of Furman Street, 17 Wendell's Reports, p. 670. In Illinois, see Haslan *v.* Galena & Southern R.R. Co., 64 Illinois Reports, p 653. In Ohio see Railroad Co. *v.* Longworth, 30 Ohio State Reports, p. 108. In New Jersey, see Summerville *v.* Erie Railway Co., 2 Zabriskie's Reports, p. 35. In Great Britain, see Queen *v.* Brown, Law Reports, 2 Queen's Bench, p. 630.

† In the State of New York, this rule was fixed by the case of "In the matter of Furman Street" (Brooklyn), 17 Wendell's Reports, p. 670, has always been approved of in land cases, and has never, to my knowledge, been questioned in cases of the diversion of water.

always be assumed, and not a *minimum*, as a riparian owner is entitled to be compensated, not on the basis of the amount of horse-power which his stream will yield him in dry seasons, nor which it will yield him in wet seasons, but upon the basis of the average flow throughout the year, in any ordinary year. In computing the amount of water-power capable of being derived from a given stream before and after diversion, experts almost invariably differ, according to which side of the case they happen to be on, upon nearly all points except as to the "fall" of the stream upon the land of the owner. Experts for the party taking the water are very apt to assume that a minimum percentage of rainfall is collectible, or that the rain fall is much less than it is popularly considered to be, and consequently the amount of available horse-power, before and after the diversion, as calculated by them, will be very much less than that derived by the experts for the property owner. There does not seem to be the slightest good reason why such discrepancies should occur, if only the *indemnification* of the owner be borne in mind, and the elements of the calculation be assumed at a figure slightly above the general average, and every doubt be resolved in favor of the party injured.

It follows, therefore, that a party who is to receive indemnification ought not to be indemnified on the basis of the actual value of the actual amount of water used, for the right to indemnification is quite independent of the mere using or non-using of his property; but, on the contrary, he should be indemnified on the basis of the amount which he could or might use under the most favorable conditions. There is no presumption of the abandonment of a water-right by reason of not using it, as the right is one which a proprietor is entitled to exercise at any and all times. The law-cases are absolutely unanimous on this point,* and if an owner chooses to slumber on his rights for years this does not indicate, or raise the presumption that they are valueless. The right to use, and the resultant right to be paid the full market-value of water taken, are not lost until an adverse easement is acquired.

* In England, see Crossley *v.* Lightowler, Law Reports, vol. 3, Equity, p. 296; Roberts *v.* Richards, vol. 50, Law Journal, Chancery Reports, p. 297. In Connecticut, Wadsworth *v.* Tillotson, 15 vol., Conn. Reports, p. 366; Buddington *v.* Bradley, 10 vol., Conn. Rep, 213. In New York, see Groat *v.* Moak, vol. 94, New York Reports, p. 115; and generally see Mr. Gould's valuable treatise on the Law of Waters, p. 226.

Where the waters of the stream are used for the purpose of producing power, the only practically ascertainable value which the stream in the majority of cases will possess will be its value for milling purposes, as its use for other purposes becomes subordinate to its use as a source of power. The value of the stream as it originally stood will depend upon each and every one of the elements that go to make up the power which can be developed by it, without reference to the actual amount of power which is actually being derived at the moment from the stream. In determining the damage the following is the proper method of procedure: First, the actual amount of available horse-power in the particular case should be determined by the expert after a careful examination of the fall, flow, rainfall and pondage facilities. Then the value of water-powers existing under as nearly as possible similar conditions should be first ascertained in the same or in adjacent localities, and the general value of such water-powers per horse-power determined. The owner should then be allowed the market-value of the actual available horse-power, as such powers are held in the vicinity of his property, in view of the standards already determined. If there are no standards of market-value in the neighborhood the value should be computed upon the basis of the most similar cases ascertainable. In each case, however, a liberal standard should be applied, and the power valued, not on the basis of the cases where the smallest prices have been paid, but upon the basis of those where the powers have brought most liberal prices. It is at this point that the real-estate broker steps in to aid the scientific expert in arriving at the market-value, for the expert's standards of value may or may not be limited to those places, the statistics of which appear in the printed tables. It is in cases where there are no existing standards to guide the experts and brokers that the difficulty is the greatest. Here the property owner should be given the benefit of any doubt that exists in the expert's mind. Then the amount of power left after the diversion should be computed, and its market-value determined in the same way. This subtracted from the market-value before the diversion will leave the damages.

In cases where the waters of the stream are used for other purposes than milling, great difficulties exist in determining the value of the water to the land for these other purposes, especially if they happen to be very different in scope, and if the water

is much more valuable to the land for one purpose than for another, and much more valuable to one owner than to another. But this phase of the question I do not propose to discuss here, as this article is limited strictly to the appraisement of water-powers; suffice it to say, that value must be determined with reference to all the possibilities which the stream possesses.

Again, the value of what is left after the diversion must be the reasonable value, not alone in view of the use to which the stream had been previously put (for this often may become zero), but in view of the most valuable or favorable use to which the residue may be put. Thus, in many cases, the flow of a stream after diversion may become so variable and fluctuating that such power as is left may be absolutely valueless. In such cases the value of the residue must be determined with reference to any use for which it may be *most* valuable. As a water-power it may be valueless, yet as a source of domestic water-supply it may possess considerable value. It will be seen, therefore, that the greatest value before diversion may be for one purpose, and the greatest value after diversion may be for a very different purpose. The market value of the whole of the owner's original power should only be awarded in cases where the residue is absolutely valueless. In such cases it is the function of the scientific expert to say whether the residue is or is not of value for milling purposes, and, if it is of no value, then it is the function of some other expert to say what it is worth for other purposes.

In many cases water-powers will be met with, which, owing to their remoteness from all centres of civilization, will not possess any actual, ascertainable market-value. In such cases, in determining values, experts will have to be guided by common sense rather than by scientific or legal principles, or existing standards.

In all cases, however, it should be remembered that the full indemnification of the owner is the object of the inquiry, not the replacement of the lost water by money or by other power, and full indemnification consists in giving the party injured the difference between the value of what he originally had and the value of what he has left. The proposition that the damage to a water-power in such cases is the cost of replacing it by steam or by some other power is not supported by law or logic, for in many cases the cost of replacement and maintenance of a like amount of power, will far exceed the original intrinsic value of the stream for any

purposes, even the most valuable, and the replacement of a water-power by a corresponding number of horse-power in steam-power, the only practically available substitute, will in many cases supply the person so compensated with an intrinsically much more valuable and available power by reason of its portability and constancy, so placing the person indemnified in a better position than he would have been in had the diversion not taken place.

As far as commissions and their deliberations are concerned, it is impossible to indicate any rules for their guidance other than the ordinary rules of law already referred to, which are supposed to govern them, and which they, alas, so often fail to observe. For this failure there can be no adequate remedy except the complete abolishment of commissions of appraisal, and the substitution for them of some other form of machinery for doing their work. The substitution of the ordinary form of trial by jury for appraisement by commission seems to be the most advisable remedy. This can only be done by legislative action, and it is to be hoped that the time may speedily come when public sentiment shall be so aroused that some steps towards the relief of this evil will be taken.

THE COALS OF COLORADO.

BY PROF. J. S. NEWBERRY.

GEOLOGICAL AGE AND RELATIONS.

THE coal-bearing rocks of Colorado for the most part belong to the Laramie group, the upper division of the Cretaceous system. It is true that there are beds of lignite of workable thickness and useful quality in the Tertiary strata, but the principal coal-bearing beds, both east and west of the Rocky Mountains, are of Laramie age, and lie at about the same geological level as those of Castle Valley and Pleasant Valley in Utah and those of Rock Creek and Evanston on the line of the Union Pacific R.R. The coal of Carbon Station is more recent, lying 1500 or 2000 feet higher in the series than that of Trinidad; as also are the coals of the Lignite Basin of the upper Missouri. This latter is Tertiary, while that at the Falls of the Missouri is much older, viz., of Kootanie age, like some of the coal basins north of the Canadian line. The Kootanie coals are Lower Cretaceous and were formed in fresh-water basins in the interior of the continent, before the submergence took place which resulted in the spread of the material forming the Dakota sandstone and the accumulation over that of the marine deposits of the Colorado group.

An interesting geological fact has been brought out by a comparison of large collections of fossil plants which I have from the Puget Sound coal series, and from the Laramie of Colorado, viz., that they are essentially on the same level, quite a number of species being common to the two floras.

All the important coal-beds of Colorado are located in one or the other of two great belts which cross the State from north to south.* Of these belts the most easterly lies along the foot hills of the mountains, and in this are located the mines of Erie, Franceville, Cañon City, Walzenburg, Cucharas, Trinidad, the Raton Mountains, etc. The coal-bearing strata of this belt never exceed 1000 feet in thickness, and there are nowhere more than four workable coal-seams with an aggregate thickness of twenty feet. In

* A few good mines are opened in detached Laramie basins in the mountains between the great coal-belts, as the mines of Sedalia and Como, but these are exceptions to the general rule.

the northern end of the belt the coal is non-coking, contains much water and oxygen, and breaks up into small pieces on exposure. At Cañon City and thence southward the coals have felt the influence of the eruptive rocks which have cut through or overflowed the formation, have become more bright, compact and enduring, and have generally acquired the property of coking. Already a great coal industry has grown up in this portion of the belt, and a very large quantity of coal and coke are exported from it for the supply of the Prairie States, or the smelting furnaces of Pueblo, Denver, and Leadville.

The coals of this eastern district are inferior in quality to those of the western part of the State, containing on an average double the quantity of ash; but they will compare favorably with any others which reach the markets they supply, and from their proximity to the large treeless area on the east, where towns are rapidly building and railroads being constructed, they have already become a necessity to the rapidly increasing population, and are destined for a long time to have an active and ready sale at remunerative prices. Heretofore the demand has been in advance of the supply, and with the opening of the new lines of railroad leading to this field, the probabilities are that, even with a greatly increased output, the same condition of things will prevail.

The Cañon City, Walzenburg and Trinidad coals have been carefully studied and tested by Prof. William B. Potter, who has made them the subject of an interesting and important communication read before the Institute of Mining Engineers and published in vol. V. of its *Transactions*.

To this carefully prepared paper of Prof. Potter, I would refer all those who desire further information in regard to the coals of this district, limiting myself to a few words upon its geology.

The Cretaceous strata, where not covered by more recent Tertiary beds, occupy nearly all the length and breadth of the "Plains," and consist of the Dakota sandstone below, and the Benton, Pierre, and Fox Hill beds above. The three latter are marine, and over most of the Cretaceous area are limestones, but toward the west, and approaching the old shore line along the Wasatch they become more earthy and carbonaceous, and in Western Colorado and Eastern Utah they are represented by 1500 to 2000 feet of black shales, everywhere containing *Inoceramus* and other Cretaceous mollusks. To these shales and limestones, equivalents of the

Benton, Pierre, and Fox Hill beds of the north and east, King and Hayden have given the name Colorado group, by which they are now generally known.

Between the foot-hills of the Rocky mountains and the summit of the Wasatch the older Cretaceous rocks are covered by sandstones and shales which contain beds of coal so numerous and important as to give to the formation the name, sometimes applied to it, of the Lignitic Formation. This, the true Laramie group, is distinct from the so-called Laramie of the upper Missouri, named by Hayden the Fort Union group, and which, in my judgment, should be considered the basal member of the Tertiary. Large collections of fossil plants made by Dr. Hayden and others in the country bordering the upper Missouri have passed through my hands, and have been described by me in a memoir to be published by the U. S. Geological Survey. This flora has also been carefully studied by Prof. L. F. Ward, who has published an important paper upon it which forms part of the Sixth Annual Report of the Director of the U. S. Geological Survey. It is entitled "A Synopsis of the Flora of the Laramie Group," but it really contains few of the Lower or true Laramie plants, and is chiefly descriptive of the Upper Laramie or Fort Union flora, of which it affords the most important review yet published. In this flora are a number of living species, such as *Corylus Americana*, *C. rostrata*, *Onoclea sensibilis*, etc., and many species found in the Tertiary rocks of Northern North America, Greenland, and Europe in strata called Miocene by Heer, but shown by J. Starkie Gardner to be Eocene.

The flora of the Lower or true Laramie has been made known to me by collections from Evanston, Black Butte, Bitter Creek, Fisher's Peak, Walzenburg, Cañon City, Crested Butte, etc. These show that there is almost nothing in common between the Fort Union and Laramie floras, and that the two divisions of the so-called Laramie group, judging from their fossil plants, which are very numerous, must be regarded as distinct formations. The older flora contains no living species, but has many things in common with the Upper Cretaceous coal-bearing rocks of Vancouvers Island and Washington Territory, is associated with marine and brackish water shells among which *Inoceramus* is conspicuous, and I have, therefore, called it Cretaceous and the upper member of that system.

The Laramie series in the eastern coal-belt of Colorado is

about one thousand feet in thickness. It shows a marked contrast in lithological characters with the Middle Cretaceous, or Colorado group, on which it rests. Heavy-bedded sandstones, sometimes conglomerates, succeed earthy limestones or fine carbonaceous shales, showing a great change in the physical condition of this part of the continent towards the close of the Cretaceous age; the sea basins shallowing, with many advances and recessions of the shore line, and locally the formation of marshes, in which peat-beds of great thickness accumulated, subsequently covered with marine, brackish or fresh-water deposits, and now important beds of coal. The physical changes here recorded apparently affected the whole great interior basin of the continent, as we find the characters and relations of the Colorado and Laramie groups to be continuous along the flanks of the Rocky Mountains, quite across the State of Colorado and, indeed, as I have learned from my own observations, from Northern Wyoming to Southern Chihuahua. In this eastern belt—which seems to have been limited in its western extension by the granitic axes of the Rocky Mountains—there are usually but three or four workable seams of coal (rarely more than two) in the section. At Sopris the lands of the Colorado Fuel Company contain three known workable seams, of which the largest has a maximum thickness of eight feet, the other two being each about four feet thick. The character of this coal may be seen by reference to the table of analyses at the end of this article, where I have given the composition of a section, from top to bottom, of the thickest coal.

The Western Laramie Belt.

The western coal-field of Colorado stretches quite across the State, from north to south, though interrupted at various points by erosion and the outpouring of vast masses of eruptive rocks, which form most of the group of mountains that lie along the flank of the western belt of the Rocky Mountains. On the San Juan and its tributaries is quite an extensive coal-field, which I traversed in 1858–59, when connected with the government parties exploring the Cañons of the Colorado, and I have ridden many miles along the north side of the San Juan, where its bank contains a continuous coal seam from 30 to 50 feet in thickness. This is, however, like all such great seams, far from homogeneous, layers of good coal two or three feet in thickness, alternating with layers

of slaty coal; but near the mouth of the Animas I noticed another seam six feet in thickness, which was fairly uniform in composition. The coals of this basin have been considerably worked in the country bordering the Animas, and constitute an important element in the mining industries of this section.

Further north the surface is occupied by vast masses of eruptive rock, and we see nothing more of the coal-strata till we pass the Gunnison. There, on the North Fork, and at Irwin and Crested Butte, we enter a coal-field which, with local interruptions, reaches north to and beyond the Union Pacific Railroad, and west to the Wasatch. The strata which contain the coal here are the geological equivalents of those of the eastern belt, but the series is much thicker, and perhaps runs higher. On Grand River, below Glenwood Springs, and at the west end of Coal Basin, 50 miles further south, complete sections of the Laramie group are shown, and we learn from them that it is not less than 3000 feet in thickness, contains sometimes as many as 8 to 10 seams of coal, some of which occasionally reach a thickness of 20 feet or more. Often 40 to 50 feet of workable coal may be seen in the same section, and this of a quality which will compare with any known in the world. It should also be said that owing to varied and peculiar conditions the coal forms several varieties, each of which has its special uses in the economy of civilization. Here we find anthracite as hard and bright as any of that mined in Eastern Pennsylvania; semi-bituminous coals similar in composition to those of Blossburg, Cresson, and Frostburg, but more compact and pleasanter to work, transport, and use; bituminous coals which yield a coke as good as that of Connellsville or Durham, and open burning or furnace coals, similar in character to the famous Brier Hill coal of Ohio, and of equal value.

Though so unlike in other respects, these coals have this in common, that they are of unusual purity, sometimes containing but 2 per cent., and rarely more than 5 per cent. of ash, and with little sulphur or phosphorus.

This coal-field is but the eastern margin of a sheet of Upper Cretaceous rocks which reaches across from the Rocky Mountains to the Wasatch. It everywhere carries coal, but the influences which have given such variety and excellence to the coals of Western Colorado, viz., the eruptions of igneous rocks, do not extend westward, and the coals of Utah are softer, less varied in character, and less pure.

Crested Butte District.

While at Crested Butte I examined the mines of the Colorado Coal and Iron Company, the coal lands, now unworked, bordering Slate River, and also the lands and mining-plant at Anthracite.

The sedimentary strata are in this vicinity considerably disturbed, the coal is locally much metamorphosed, and over large areas, eruptive masses forming high peaks and ridges occupy the surface.

The Colorado Coal and Iron Company have evidently a valuable coal property at Crested Butte, the principal coal-seam attaining a thickness of 6 feet, lying favorably for working, and furnishing coal of good quality, free from bone, and making coke which contains about half as much ash as that made at Trinidad. The coke-plant consists of 125 ovens of beehive pattern. The coal is coked only 36 hours, and is therefore somewhat tender, but strong enough for lead-smelting, for which it is principally used. The demand for the coal and coke is greater than the company can supply with their present facilities, but a new opening has recently been made with considerable additions to the machinery, by which the output will soon be largely increased.

Between Crested Butte and Anthracite, a distance of four miles, the valley of Slate River is bounded on the west by a continuous and abrupt mountain composed of Laramie rocks, in which a seam of coal has been opened at various points, but is not now worked. It is anthracite of fairly good quality, from 4 to 5 feet in thickness, but somewhat shattered and working small. Snow-slides from the mountain side have embarrassed and limited mining operations here, but it is obvious that these could be prevented by barricading, as has been done on Aspen mountain; timber is abundant on the spot, and barricades could be cheaply constructed.

The Anthracite coal-mine has now been worked for several years by the Colorado Fuel Co., has railroad connection with the Denver market, and its product is there a well-known staple. The coal-seam is from 4 to 6 feet in thickness, and the coal is a hard, bright anthracite, resembling in appearance and not inferior in quality to that taken from the Pennsylvania mines. The coal-lands connected with this mine form a mesa which rises more than a thousand feet above the valley of Slate River, and the coal is worked near the top. It has a general dip toward the valley, and the area

available for working is something like 500 acres. The coal descends to the railroad by a double-track incline, passes through a breaker to the cars, and the whole plant has the aspect of a Pennsylvania anthracite mine. Unfortunately there is yet no market for the smalls, and they have accumulated until they have formed heaps of thousands of tons. The quantity of anthracite in this region is apparently quite limited; perhaps the mountain opposite the Anthracite mine may be found to contain more than is yet known to exist, but, without further discoveries, it would be unsafe to estimate the coal area of Slate River Valley at more than 2000 acres.

At Irwin, 14 miles west, there is an area of anthracite of 1500 or 2000 acres. The coal is of good thickness and quality, as silvery and brilliant as any from the Lehigh basin, but this field has as yet no outlet by railroad.

The anthracite of Gunnison mountain, of which so much was hoped, has proved to be very limited in quantity, and is for the present, quite inaccessible; that of Ragged mountain, still further north, is open to the same objection, and though of good quality, is shown by the investigations of Mr. R. C. Hills to be cut off at no great distance in the rear of the outcrop by the eruptive rocks which have metamorphosed it, and the quantity is, therefore, small. The Muncie Anthracite, north of the last-mentioned locality, has been purchased by the Midland Railroad, but it is questionable whether it will prove sufficient in quantity and quality to warrant the large expenditure necessary to open a way to it.

The localities enumerated include all the important deposits of anthracite coal yet known in Colorado. From its mode of formation the area of anthracite must necessarily be small. It is confined to the localities where the eruptive rocks have burst through the coal series, and the influence they have exerted has been sufficient to produce anthracite only for a short distance. Hence we may conclude that the anthracite of Western Colorado, excellent as it is in quality, is not destined to be an important factor in the future history of the State.

Coals of Gunnison Mountain.

West of Crested Butte the Laramie coal-series is pierced by several great masses of volcanic rock, a rhyolite, light gray in color, with numerous large, often opalescent, crystals of sanidin.

This composes Mt. Beckwith, Mt. Marcellina, the Ragged mountains, Mt. Gunnison, etc., with numerous dikes and intrusive sheets which penetrate the sedimentary strata to some distance from the volcanic vents. From these mountains one looks out westward on to the broad plateaus of Grand and Battlement Mesas, an unbroken portion of the sheet of coal-bearing rocks which occupies all the interval to the Wasatch. Between the eruptive masses referred to the strata are generally much warped and broken, but along the North Fork of the Gunnison in many places they lie nearly horizontal, the coal-beds being above drainage and accessible. On the east side of Mt. Gunnison a plateau of this character forms the most interesting and valuable tract of coal-land I have anywhere seen. Coal creek cuts into this plateau to the depth of 500 to 1000 feet, exposing at the bottom the Colorado shales, and above them the base of the Laramie, soft yellow sandstones and gray argillaceous shales. Near the top of the cliffs lies an intrusive sheet of rhyolite, similar in general appearance and relations to the Palisades on the Hudson river. In this section, in addition to smaller beds, are four finer coal seams than I have elsewhere seen in one exposure. Of these, the first and lowest is 10, the second 13½, the third 10, and the fourth 10 feet in thickness. The uppermost lies within a few feet of the trap-sheet, and at places this comes down immediately upon it, converting it into anthracite. The third seam is 25 feet below the fourth, and they are much alike in character. The second seam from the bottom is 13 to 15 feet in thickness, having been somewhat eroded by the current which spread over it the material of the sandstone roof. This has one parting, a band of smut 4 to 6 inches in thickness about 6 feet above the base; a good feature in the seam, as it will permit its being worked in two benches, and make the "bearing in" under the upper bench easy. With the exception of this parting the coal is very homogeneous and pure. Like many other Laramie coals this contains numerous particles, scales, or lumps of a yellow resin which resembles amber, but is a secondary product, having been distilled from the substance of the coal long subsequent to its formation, and accumulating in its joints and cavities.

The character of all the coal seams on Coal creek is similar, though the upper seams are somewhat dryer from their proximity to the trap. All are hard, bright, and homogeneous, working large and coming out in blocks like quarry stone. To the experienced

coal-miner nothing could be more attractive than the solid, black, shining walls they present when opened.

In composition these coals are most like our open-burning bituminous coals of the Alleghany coal-field, but contain more gas, and show little tendency to coke. They contain 4 to 5 per cent. of water, and from 4 to 7 per cent. of ash; the second and fourth seams ½ per cent. of sulphur; the third nearly 1½ per cent.; in phosphorus they are all low. The lowest seams of the series is not as well shown as the others, but it is apparently softer and will probably coke better.

The coals of the country drained by North Fork, where not locally converted into anthracite, are exemplified by those just described. Some of them will coke, but they must be generally classed as open-burning. Whether they can be used in the raw state for smelting remains to be seen, but, in my judgment, with proper appliances and management this may be done. As steam coals and household fuels they have no superiors, and it will not be many years before they will be taken through the mountains by railroad in large quantities to supply the ever increasing want of good fuel in the Prairie States.

The Coals of Coal Basin.

About 40 miles north of Crested Butte and as far south of Glenwood Springs is a district which has been called Coal Basin. This is one of the most peculiar and interesting areas which I examined in Western Colorado. It is evident that the Laramie Coal Measures, which before were nearly horizontal, were once at this point raised into a dome by the protrusion of a mass of eruptive rocks. The central portion of the dome—doubtless considerably broken up—has since been removed by erosion to form a basin 5 miles long by 3 miles wide. The centre of the basin is excavated deeply into the Colorado shales, the middle member of the Cretaceous system of this region, while its rim is formed by the Laramie group 2000 to 3000 feet in thickness, which dip away from the centre in every direction. In the cliffs which border the basin the coal-seams are exposed and accessible in many places; the number and thickness of these seams vary considerably, owing to local changes, and to the different degrees to which the margin has been eroded. Where most numerous and distinct there are five or six workable seams, viz., three above the lower sandstone; one,

sometimes two or three, above the middle sandstone, with one in the upper sandstone, and several small seams above. At the west end of the basin the lower three seams are closely approximated and in one place run together, forming what may be regarded as a single seam about 18 feet in thickness. Generally the three seams are separated by a few feet of sandstone.

The eastern rim of the basin is formed by rocks older than the Laramie, viz., the Colorado shales and Dakota sandstones, and below these the Jurassic and Triassic strata, which form the walls of the very picturesque cañon of Coal creek, the outlet of the basin. These walls are 2000 feet in height, composed chiefly of purple sandstone weathered into all sorts of fantastic and imitative shapes. Rising abruptly from the green bottom lands of Crystal river they form one of the most striking and beautiful portals I have ever seen. These older rocks are here thrown up by a fault or sharp fold which crosses Crystal river obliquely above the mouth of Coal creek. South of this line the Laramie rocks come down and form for many miles the walls of the valley of Crystal river, but apparently contain no very good or accessible coal. Chair Mountain on the west side of the valley contains some anthracite, but it is too much broken up to be of any value.

Twelve miles south of Coal Basin Yule creek joins Crystal river from the southwest. For several miles the valley of this stream is excavated in Palæozoic limestones in which is the finest belt of marble yet discovered in the United States. The beds stand nearly vertical, are about 150 feet in thickness, and of this nearly one-half is pure white, and would be classed as statuary marble. Toward the top of the deposit are some layers of the purest, loveliest blue marble ever seen.

The coals of Coal Basin are all of the same general character, though differing considerably among themselves in the degree to which this character is developed; that is, they apparently all belong to the class of coking coals, and are generally of good quality, containing a small amount of ash and sulphur.

At the eastern end of Coal Basin the lowest coal seam lies high up in the hills, and is widely separated from its fellows. It is 7 feet in thickness, looks well, but is peculiar in composition and inferior in quality to any other coal observed in the basin, since it contains 10 per cent. of ash and 0.142 of phosphorus. Toward the west end of the basin all the coal seams come down, and the

entire section of the Laramie rocks is presented in one cliff nearly 3000 feet in height. At its base the lowest three seams are united in one, or closely approximated, giving 18 feet of coal in three benches or distinct seams. They are very much alike in appearance and quality, containing about 1 per cent. of water, 23 per cent. of volatile matter, 70 per cent. fixed carbon, 3 to 7 per cent. of ash, one-half of 1 per cent. of sulphur, and 0.011 of phosphorus. A higher seam, from 7 to 8 feet in thickness, is of similar character and purity. These coals make excellent coke, and as they underlie an area of many thousand acres, are capable of furnishing an inexhaustible supply of fuel for the future iron and lead smelting of Colorado.

The coal properties on the south and west sides of Coal Basin belong to the Colorado Fuel Co., of which Mr. J. C. Osgood is President; those on the north side of the Basin have been acquired by the Midland Railroad Co.

To connect the coal mines of this district with the markets, a railroad is being constructed down the valley of Crystal river to Carbondale (Satank), where it will join the D. & R. G. and Midland roads, already in operation.

Glenwood Springs District.

At the junction of Roaring Fork with Grand river is located the town of Glenwood Springs. Although but three years old, it has a population of 3000, is rapidly growing, and is remarkably well built. The location is picturesque, there are great hot springs here, and it is evidently destined to be a very popular place of resort. Its commercial and manufacturing advantages are also great, and it promises soon to become the second city of Colorado, second only in business and population to Denver. The valley of Grand river in which it is situated is the only feasible route for railroads through this region. The D. & R. G. and Midland roads have already reached this point, the C. B. & Q. will soon follow, and all these will be extended to Grand Junction and thence westward.

Coal is also destined to be an important factor in the future prosperity of Glenwood. The coal-deposits of Coal Basin which have been already described; those of Thompson Creek recently opened and connected with the markets by the D. & R. G. road, and those of Jerome Park and Piñon Basin, which lie still nearer,

must all bring their products to or through Glenwood Springs. The coal-mines of Thompson Creek and Jerome Park I did not visit, but they are being vigorously worked, and the coal resources of these districts have been so far explored and tested as to prove beyond question the abundance and excellence of the fuel they will afford. The Jerome Park properties are controlled by the Midland Railroad, and are being developed under the direction of Mr. W. B. Devereux, a graduate of the School of Mines, and Mr. G. C. Hewett, an experienced and able coal expert from Pennsylvania. In Jerome Park, Mr. Hewett has already established a coke plant, using a coal which contains only about 2½ per cent. of ash, and producing an excellent article.

Piñon Basin.

Eight miles west of Glenwood Springs a line of disturbance crosses Grand river in a northwest and southeast direction, by which all the sedimentary strata of this region are thrown up at a high angle, exposing the most complete section to be found anywhere in Colorado. This includes 1, Granite; 2, Potsdam sandstone; 3, Palæozoic limestones (Silurian and Carboniferous); 4, Trias; 5, Jura; 6, Dakota; 7, Colorado; 8, Laramie. All these strata, from the middle of the Trias to the top of the Laramie, are visible at one view in the banks of South Cañon. The Laramie is here about 3000 feet in thickness, and, as is usual in all this region, contains near the base heavy masses of sandstone. These have been left in relief by the erosion of the Colorado shales on the north and the soft argillaceous shales of the Upper Laramie on the south, forming a "hog's-back," which rises 2000 feet above Grand river, borders its south bank for some miles, and crosses it diagonally at Chapman. This "hog's-back" holds a remarkable group of coals which are destined to play an important part in the future history of Colorado. The productive coal territory is held by the New York and Colorado Coal Co., represented by Mr. Pray; the Colorado Fuel Co., of which Mr. J. C. Osgood is President, and the Midland Railway Co. The coal seams lie between the sandstones, and their outcrops are 1500 feet or more above the river. They dip toward the south at an angle of 45° to 55°, and they will be, therefore, easily accessible by tunnels driven into the hog's-back from its northern base on the banks of Grand river, and in the bottom of the valley through which three railroads are to pass.

The quality of these coals is excellent; indeed, they exceed in purity any others known to me. They are open-burning in character, resembling most in composition the Brazil coal of Indiana and the Brier Hill, of Ohio, but the seams are thicker and the coal is purer than even are these famous furnace-coals; the best two seams in the series being about 8 feet each in thickness, remarkably compact and homogeneous, and containing only about 2 per cent. of ash, 4½ per cent. of water, one-half of 1 per cent. of sulphur, and very little phosphorus.

The succession of coal seams in Piñon Basin is as follows in ascending order, viz.: Immediately above the lower sandstone seam No. 1, 3 feet in thickness; below the second sandstone, and cropping out near the top of the ridge seam No. 2, 22 feet thick. Above the second sandstone, in rapid succession, follow seam No. 3, 4 feet thick; No. 4, 7½ feet; No. 5, 3 feet; No. 6, 8 feet, with several others, 2 and 3 feet thick, above. All these seams appear to be much alike in character, except the big seam (No. 2). This has been but imperfectly opened, and the outcrop is very dry and tender; just what it will prove when more deeply penetrated cannot yet be said, but two analyses made in the assay laboratory of Columbia College show a very remarkable composition, viz., water, 10 per cent.; volatile matter, 55 per cent.; fixed carbon, 29 per cent.; ash, 5½ per cent.; sulphur, ⅓ per cent. In all my experience in coals, I have never met one which showed so large an amount of volatile matter at the outcrop. I suspect it is to be explained, in part at least, by its ready oxidation and the escape of a large portion of its carbon as carbonic acid. This is rendered the more probable by the analysis of a sample taken from the same seam in another locality by Mr. R. C. Hills, who reports in it 15 per cent. of moisture; 15 per cent. of gas; 56 per cent. of fixed carbon; and 13 per cent. of ash. I shall look with special interest to the results of future explorations of this remarkable coal seam.

The uses to which the coals of Piñon Basin will be put are clearly indicated. As household fuels and for the generation of steam they have no superiors, and they are so compact and will work so large that they will bear transportation to any distance. For the manufacture of illuminating gas they would seem to be well adapted, as the amount of volatile matter is considerable and that of sulphur very small. Unfortunately they do not coke,

but I have little doubt that with proper management they can be successfully applied to the smelting of iron and lead.

Coals of the White River Country.

The White river coals are simply an extension northward of those which crop out on Grand river, and they have been opened at various intermediate points. I have not myself been through this region, but I learn from Mr. R. C. Hills who has carefully explored it, and who has a better geological and technical knowledge of the coals of Colorado than any other man living, that the coals north of Grand river are inferior in quality, quantity, and variety to those found in the country between Glenwood Springs and Gunnison. So in going down Grand river from Piñon Basin the Laramie coal series is found continuously to Grand Junction, and thence westward to the Wasatch. Much of this country I have been over and have examined the coal in a great number of localities, and while the seams are of good thickness and fair quality in many places, they are less thick, and the coals are less varied and pure than in the belt of country described in this paper. At Coalville, Castle Valley, Pleasant Valley, Cedar City, and Kannarra are seams of coal which have already been somewhat worked and have been proved to be of fair, and sometimes of excellent quality. The same is true of the country bordering the Union Pacific railroad, where at Evanston, Rock Creek, Rock Springs, etc., large quantities of coal are mined which is much esteemed for domestic fuel and for the generation of steam. Yet nowhere in all this region is the coal equal in quality, quantity, and variety to that found in the country between Grand river and the Gunnison. Adding to this belt the coals of White river and the intervening district, we have some 4000 square miles of coal-land in Western Colorado which will bear comparison with any equal area of Carboniferous coals in the valley of the Mississippi. The importance of this coal-field to the inhabitants of Colorado and the adjacent prairie region cannot be overestimated; and, however productive the mines of gold and silver of this highly favored State may become, I cannot but think that her coal-mines will prove the most important source of her wealth. I subjoin a table of analyses of Colorado coals made for me in the assay laboratory of the School of Mines:

Analyses of Colorado Coals.

Coal Examined.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.	Phosphorus.
Sopris entire seam, 8 feet thick	0 799	30.256	59.328	8.513	1.103	0.0437
Anthracite anthracite	1.560	5.930	88.710	3.750	0.48	0.067
Irwin anthracite	2.696	6.545	84.111	5.865	0.79	0.0272
Piñon basin, 7½ ft. seam	4.720	39.372	53.487	1.997	0.421	0.04767
Piñon basin, 8 ft. seam	4.587	39.876	53.028	2.132	0.369	0.027
Piñon basin, 22 ft. seam, outcrop	10.	55.067	29.062	5.530	0.327	0.0332
Coal basin, Claim F	1.089	37.974	52.956	8.981	0.834	0.03859
Coal basin, Claim H	0.686	32.682	56.036	10.140	0.454	0.142
Coal basin, 20 ft. seam, outcrop	0.615	23.532	67.30	7.993	0.558	0.011
Coal basin, 20 ft. seam, upper bench	1.9	23.7	71.1	3.6	R. C. Hills.*	
Coal basin, 20 ft. seam, middle bench	1.1	22.1	72.3	4.5		
Coal basin, 20 ft. seam, lower bench	1.9	20.6	73.0	4.5		
Gunnison upper seam, 10 ft.	3.803	40.155	51.178	4.341	0.523	0.029
Gunnison upper seam, anthracite	0.91	9.313	80.932	8.298	0.547	0.039
Gunnison second seam, 10 ft.	4.927	38.832	47.906	6.944	1.388	0.054
Gunnison third seam, 13½ ft.	5.234	41.916	48.434	3.946	0.468	0.080
Cañon City	5.67	36.54	50.02	7.76	1.05	0.045

THE RELATION OF THE ELECTRICAL UNITS OF MEASUREMENT TO THE DYNAMIC UNITS.†

BY F. R. HUTTON.

ATTENTION has been called in some of the electrical text-books to the parallelism between the phenomena of the passage of electric energy along a conductor, and the phenomena attending the flow of water in conduits, for mechanical and industrial purposes.

It is the intention in the present paper to point out the existence, and analyze the nature of this relation.

* Mr. Hills tells me that he has learned by making several hundred analyses of Laramie coals, that to avoid loss—underestimate of fixed carbon and overestimate of ash,—the combustion should be made in a double crucible.

† From a paper read at the Quarterly Reunion of the Alumni Association of the School of Mines, May 25th, 1888.

The new metric dynamic units are not in use among mechanical engineers because many of them are of more interest in the physical laboratory to denote smaller quantities, than in the practice of the mechanical engineer handling the commercial sources of power. They have, however, the same interest and value in dynamic calculations as in the chemical laboratory, inasmuch as most of the calculations are reduced to a skilful manipulation of the decimal point.

In these new dynamical units, the unit of length is the centimetre, the unit of weight is the gramme, and of time the unit is the solar second. Quantities in these units are usually called C.G.S. quantities, and it is an interesting commentary upon the impracticability of the metre as a unit of length to observe that it is considered inconveniently large even by those who favor the conveniences of a decimal system, and one whose units are inter-related.

In the C.G.S. system, the fundamental unit is called a *dyne*, and is the force which will communicate a velocity of a *cm.* per second to a gramme of matter.

If a dyne (which is a force) acts through a space of one *cm.*, a certain work is done upon that gramme of matter, and such unit of work is called an *erg*. Ten million ergs = 1 joule (10^7 ergs) = 0.7373 foot-pound.

The French calorie is therefore a number of ergs (gramme of water raised 1 degree C.), and calculation shows it to be 42 million ergs or 4.2 joules.

This work conception, however, does not involve the idea of time. When the time unit is introduced (just as we pass from foot-pounds to horse-power in the ordinary units) a joule per second of work is called a *watt*, which is, therefore, ten million ergs per second, and has been called a unit of *activity*.

TABLE OF C.G.S. UNITS.

1 Dyne = Unit of Force = force necessary to impart a velocity of 1 centimetre per second to 1 gramme of matter.
1 Erg = Unit of Work = 1 dyne acting through 1 centimetre.
1 Joule = 10,000,000 Ergs = (10^7 Ergs) = 0.7373 foot-pound.
1 Calorie = 4.2 Joules = 42 million ergs = gramme-centimetres necessary to raise 1 gramme of water 1 degree C.
1 Watt = 1 Joule per second = $\frac{1}{746}$ British horse-power per sec.
1 Brit. Bd. of Trade Unit = 1000 Watts = 1.34 standard horse-power per minute.

If, therefore, we were to apply these units for illustration to the raising of water in a tube or column pipe, whose cross-section (1 square centimetre) was such that a centimetre in height weighed one gramme, we should do an erg of work for every centimetre of lift, and ten million centimetres of lift per second would call for the expenditure of a watt, which is but $\frac{1}{746}$ of a horse-power.

We see thus why these units are so unsuited for engineers' use. But they can be very easily multiplied by tens so as to be made useful when the time is ripe for their use, with suitable names.

For the electrical engineer, however, dealing with currents often of slight intensity, these units are most convenient. For his use there have been certain extensions of the application of the C.G.S. units which have come into general acceptance. Let two magnets of equal strength be so selected that when held a centimetre apart, their attraction for each other is exactly one dyne. If an electric current be graduated in a circle of copper wire whose radius is one centimetre, so that it will attract one of these magnets with a force of π dynes, each unit of length of that current is said to have a current of ten *ampères*. In other words, the ampère is the unit of current of electricity per second, and is a current of one-tenth that which produces in a unit's length of conductor an attraction of a unit force in dynes upon a unit magnetic pole at a unit's distance.

The ampère is above defined as being the current per second. Some confusion in this regard has arisen from the fact that electric forces act so rapidly that an instantaneous impulse may be said to be a current of so many ampères. But since the ampère is thus related by definition to the dyne, which is such a force as acting *for a second* will produce a centimetre of velocity at the *end* of such second, we see that the ampère cannot properly be claimed to be a unit independent of time.

Let us then at this point proceed to establish more exactly and definitely than heretofore the parallels between the electrical and the hydro-dynamic units. Suppose a pen-stock, one centimetre of area in cross-section, and conceive the outlet at the bottom to carry a current of water against the buckets of an overshot water-wheel, turning on a horizontal axis, and receiving the discharge of water from the pen-stock without loss or leakage. The velocity of rotation of that wheel would be the result of the current of water passing over it. Let the orifice or gate in the pen-stock be so

graduated in relation to the head of water causing the flow, that a unit quantity flows per second and maintains the unit velocity of the wheel. The flow of water could then be stated in terms parallel to the ampère unit. The velocity of rotation of the wheel is parallel to attraction in dynes, due to the current in ampères.

Suppose now, however, that the head remaining constant, a number (n) of similar pen-stocks are arranged side by side, discharging upon a row of similar wheels mounted upon a continuous axle. As the head is the same, and the wheels are turning without resistance, by the hypothesis they all have the same velocity ($v^2 = 2gh$); but it is obvious that the quantity of water which flows per second is n times that required for one wheel. The current in ampères is not altered, but the quantity of electricity passing over the greater surface of conductor is necessarily greater. The electrical unit for quantity is called a coulomb, and is paralleled in the hydraulic parallel by the weight of water which would pass when the current had a unit velocity through each gate.

The wheel and the water are moving so far without resistances. Conceive a Prony-brake lever to be put on the shaft of the overshot wheel. Let this brake be weighted to act as a dynamometer to slow down the flow of water or electric fluid, and produce a resistance equal to that offered by a column of pure mercury of one millimetre in section and 106 centimetres long. This resistance of conductor, or friction of brake is called the legal ohm, which is 1.0112 of the Brit. Assoc. unit, whose length in mercury is 104.86 centimetres, at 0 degree C. If we wish still to keep up the standard velocity of wheel, which is the ampère measure of the analogic discussion, we cannot be independent of the *head* of water in the tube. We must have a dynamic head of water to produce the pressure to turn the wheel: we must have an electromotive force to maintain the current. The electrical unit which corresponds to feet in the hydraulic parallel is the *volt*. The volt causes a current of one ampère against a resistance of one ohm. The volt is the measure of the difference in electrical tension or potential, or in electrical level of two points in an electrical system or series, and is so related to the other units that, to produce a unit current *against* a difference of potential of one volt requires the expenditure of one hundred million ergs of energy. That is, to force a coulomb of current against a volt of electrical head requires one joule, which, therefore, = 1 volt-coulomb. When an ampère or

one coulomb per second of current has to be forced against an electrical head of one volt, there has to be expended one watt = one volt-ampère. One volt-ampère, therefore, being a watt, is capable of overcoming a resistance of $\frac{1}{746}$ of a horse-power at the friction brake of the water wheel, or, by inversion, it will require $\frac{1}{746}$ of a horse-power to produce a volt-ampère of electro-motive force. Here, then, our dynamic circuit is complete; the two paths, electric and hydraulic, are shown to be but parallels, and the reasoning, the units, and the conceptions are the same in both fields, and the facile and intelligent handling of the electric units is only possible as the result of a well-grounded mechanical experience.

There are but two other electrical units of dynamic interest, and in use by electrical engineers. To get the parallel for these, we must abandon the exact form of the previous simile, but the conceptions will remain. The *farad* is the unit of capacity of a conductor which holds a current of one coulomb in quantity at a pressure or tension of one volt. Let our pen-stock be one centimetre in cross-section and one centimetre high, closed at the top and bottom, and let a U-tube be connected to it, the U-tube filled with water to act as a pressure gauge or manometer. Conceive air to be pumped into the pen-stock until the water registers an internal pressure of one centimetre of water. The air at this unit pressure (unit quantity at unit tension) parallels the electric farad. The more air pumped in, the higher the pressure, until the limit of the pump and power are reached; similarly, the conductor can be charged with farads, until its potential or tension equals that of the charging apparatus.

The last unit is the *Gauss*, which is the unit of magnetic field of dynamos and other magnetic masses. It is the measure of the strength of field, such that a length of one million centimetres of wire, moving across the lines of force at a unit velocity (1 centimetre per second), develops a unit of electro-motive force (1 volt). It is 100 times the C.G.S. unit field, which is one which acts on a unit magnetic pole with a force of one dyne. The mechanical parallel for this is found in Pitot's tube, and corresponds to such an initial velocity of current against the open curved end, that when moved against the stream at a unit velocity there shall be produced a piezometric head of one centimetre.

It will be scarcely necessary in closing this discussion to call attention to the fact that the names of these new units are all taken

from those of distinguished experimenters in the electric field, and that the ampère as a unit, has replaced the old weber as a unit of current.

Below are tabulated the conclusions reached in the foregoing:

Name of Unit.	Unit of	Dynamic Parallel.
Ampère.	Current.	Pounds of water per second.
Volt.	Potential, Tension or E.M.F.	Head of water in linear units.
Coulomb.	Quantity.	Pounds of water.
Joule and Erg.	Work.	Foot-pounds.
Watt.	Power.	Horse-power.
Farad.	Capacity.	Cubic units at one atmosphere.
Gauss.	Field.	Piezometric level.
Dyne.	Force.	Force.

DEFINITION OF "THE ENGINEER."*

BY ECKLEY B. COXE.

An occasion like this, when an engineer, engaged in the active duties of his profession, but who is really more of a business man than a scientist, is called upon to preside over the deliberations of a body so distinguished, and so eminently scientific as the one that I now have the honor of addressing, must, of course, impress itself very strongly upon him, and give much food for reflection. His mind naturally turns back to review his professional life, from the time when he began as a student his technical education; many ideas, opinions and reflections, which have been more or less forgotten or pushed aside in the rush of business, come back, and again force themselves upon his attention; such, at least, has been the case with me.

As my life has been devoted exclusively to the mining of coal, and as I have been engaged in no special scientific investigations like so many of those around me, I cannot offer for your consideration original observations or suggestions upon any important scientific subject to which I have specially devoted myself, but it seems to me that I might not unprofitably occupy your time at the opening of this

* Address delivered by the Vice-President of the Mechanical Science Section of the American Association for the Advancement of Science, at the New York meeting.

session by asking your attention for a few minutes to some thoughts, which, during the last quarter of a century. have, from time to time, in a more or less desultory way, impressed themselves upon me, with reference to the subject of engineering.

Engineering is the youngest of the professions, and, with the exception of the military branch of it, may be said to have been practically unknown a century ago; there was, of course, much work, now considered within its domain, which was done by architects and others, but, as a well-defined recognized calling, it may be considered one of the creations of the nineteenth century; and yet, it has made such great advances, has broadened so much, and is now being divided and subdivided in so many ways, that it is doubtful whether it can properly be considered any longer a single profession. I do not wish to discuss here the division into the mining, civil, mechanical, electrical, hydraulic and other branches; that has been done by other hands, much abler than mine. How deep, how important and how real these divisions are, is well shown by the large and flourishing societies which have sprung up, and are devoting themselves with so much vigor and effect, to almost every one of them. But, within the last twenty-five years, another equally important change has been taking place which, it seems to me, is destined to produce at least as great an effect as the subdivision referred to above, upon the future of our vocation. Engineering is now no longer a profession only. It may be also a science or a business, that is to say, the student, when he enters college and takes the engineering course, may, with perfect propriety, look forward to being a man of science, a professional man, or a man of business, and it is not only very possible, but very probable, that he might make a success in one and a comparative failure in either of the other careers. Such, at least, has been my experience.

Let us pause for a moment, and consider the exact meaning of the words engineer and engineering: they, as well as the word "ingenius," are derived from the Latin "ingenium," which in turn come from the verb "gigno," to bring forth or produce; they involve, therefore, the idea of originating, of advancement, of development, of passing from the known to the unknown, from the certain to the uncertain, from that which has been accomplished to that which is desired. In other words, so far as their derivation is concerned, they involve the idea of evolution and progress,

and we have but to look around us in any civilized country of the world to see how well this fundamental principle has directed the minds and hands of those engaged in the practice of the profession. This may be well called the age of engineering, as it is called the age of progress.

But we must remember that the engineer is not a creator; he never makes something out of nothing; he develops, enlarges, expands, evolves; sometimes, it is true, in special cases, to such a great extent, or with such rapidity, that the result to which he attains may seem almost a creation to all but the closest observers, but this is a rare exception, not the rule; ordinarily, the progress is very slow, and sometimes almost disheartening. Very early in the history of engineering, in fact, almost before it could be considered a profession, it became evident that facts and scientific data, which could only be obtained by long, careful, and laborious experiments, were absolutely essential to those practically engaged in the prosecution of engineering; that, however correct the reasoning, however brilliant the intellect, however careful the calculation, all would be useless, unless the properties of the material used, and the law of nature that would be likely to be called into play, had been carefully determined by the most thorough scientific investigation and experiment. There is no better way of impressing upon our minds how important, nay, how absolutely essential, such data and such investigations are, and of realizing how great has been the amount of scientific work that has been placed at our disposal, than to take up any engineer's pocketbook, not the best or the fullest, but one of the ordinary ones, and examine for one's self how much of what we use every day, and of what we now consider almost axioms, is the result of scientific study and experiment, and was unknown, or, at least, so little known and so uncertain, as to be practically of no value less than a century ago.

As the number of these original investigators increased widely, and as the data accumulated by them became more and more voluminous and valuable; and as the results of their labors were published in no one country and in no one language, but were to be found in the scientific journals and text-books of all civilized nations; much the greater part of these facts, so essential to every engineer in active practice, was accessible only to those who had sufficient means to procure the books and periodicals which contained them, or were so situated as to be able to use one of the

great public libraries which were then much more rare than now. Even where the information was accessible to them, very few of those who really had the greatest need of it had sufficient time at their disposal to enable them to make use of the very valuable material, disseminated, as it was, so widely. Such a state of affairs could not, of course, exist for any great length of time.

There is a class of minds to be found in all professions which are specially fitted for the work of gathering together exactly such data, and of placing them in such a shape as to be readily accessible, and in the most appropriate form for practical use. Sometimes with this faculty or capacity is combined that of being able to deduce from such well-prepared tabulated statements of a large number of facts relating to some one natural principle, a general law contained in a few words or a comparatively simple formula, by which most of the data in question can be expressed in a mathematical form. Newton's "law of gravitation," and Darwin's "law of the survival of the fittest" are among the highest evidences of this power. The mathematical discussion of such formula often leads to results of the highest importance when undertaken by such men, who, though far from common, are nevertheless to be found in all branches of natural science, and they are probably as well represented in the American Association for the Advancement of Science, as in any other school of scientists. I do not mean, of course, in absolute numbers, but in proportion to the comparative rarity of this type of mind. It is to these two classes of scientific workers that the profession of engineering practically owes its existence in its present state. Their remuneration, I am sorry to say, has been very meagre, that is, in a pecuniary point of view. Mentally, they have been undoubtedly well paid, for labor of this character brings probably the highest intellectual pleasure of which the human mind is capable. The pecuniary unselfishness of these classes of men has become proverbial; to the average man of the world it is absolutely incomprehensible.

Until a comparatively recent time, there was, except in a few special cases, but little provision made to aid these unselfish workers, and much of the best of this kind of scientific work was really done in poverty, by those who not only were not paid for it, but who really had to deprive themselves of many things we consider necessaries of life to obtain the means of carrying on their investigations. They were recruited from various sources: many began as

teachers in the few technical and scientific schools that then existed; but, recognizing when instructing their classes the want of better and more accurate knowledge of certain physical phenomena, were induced by their love of the subject, to endeavor by experiment to supply that need. Others again, who, by some happy accident, had had their attention directed to physical science, passed from the laboratory to the lecture-room, and through a long and useful life combined the two callings. Those, however, who, during their whole career, either as experimenters, compilers, or mathematicians (using the latter word for want of a better, to cover that class who have generalized and placed in a mathematical and exact form the result of the labors of others), confined themselves to their specialty, were generally considered by most men as good-natured, harmless, and rather eccentric individuals, whose function in life they did not understand, and the valuable results of their mental labor they did not appreciate, although they might have an indistinct idea that, on some exceptional occasion, the information such men were accumulating might be useful.

The *practical engineer*, the engineer as the world understood it, was at first developed in the workshop or in the field; he may in some cases have begun with a little scientific training, but this was rarely the case. He was generally a man of broad common sense, with great capacity for work, open to conviction and with a strong desire to improve himself. His professional training was acquired chiefly in the active, practical work of his calling, but, whenever the occasion presented itself, he availed himself of whatever books on natural philosophy or special technical subjects came to his hand. He grew with his profession and helped to advance it. The careers of such men as George Stephenson and James Watt give, it seems to me, a good idea of the power of certain minds, and of the development of which they are capable, even where circumstances have not been particulary favorable. The success of such men is often referred to, as showing of how little importance a scientific training is to the engineer. How often have I heard intelligent people, who have only examined the subject superficially, say, "Look at that man! he never had any college training, and see what he has accomplished; now, look at that other! he has had the very best educational advantages, and he has done absolutely nothing." But we all know that the very roughest manipulation may sometimes make an excellent tool out

of a good piece of steel, while the most careful handling, the best workmanship, can never do that with a radically bad piece. The older members of the profession, those with whom I came in contact as a boy, when I first had my attention directed towards it, were almost without exception self-made, self-instructed, self-developed men, but "there were giants in those days."

The demand for men to undertake the direction of the great public works which were started in all parts of the United States during the early part of the century, naturally brought such men to the front; there were no schools and colleges in which they could be instructed, nor were there any teachers capable of instructing them. They came to the front, and maintained their position by mere force of brains. Among the younger men who were associated with them were some graduates of the few technical schools, mostly European, or of the scientific courses of some of the colleges, that were already beginning to realize the importance to the rising generation of a chance to prepare themselves for such a field of labor, and to endeavor, as far as was then possible, to afford them the opportunity. When the good work was once started, the demand for the services of graduates of these colleges soon became too great for the supply; and schools, where technical instruction of the highest order is given, have been established all over the country, which is now dotted with institutions of this character, and the public works, throughout the whole United States, bear witness to the eminent abilities and thorough training of a host of their graduates.

The above, though a very brief and imperfect description of the manner in which the profession of engineering has grown during the present century, is, in the main outline, correct.

Much of what I have said is the result of personal observation, and much I have learned from conversing with the older members of the profession with whom I have come in contact since I was a boy. As long as I can remember, nothing ever gave me more pleasure than to listen to the stories of how the pioneer engineers of our country encountered and overcame great difficulties with the very imperfect and limited appliances they had at their command.

At the present day engineers, no matter what may be the special branch to which they are devoting themselves, can be divided into three general classes: The first class includes those engaged in purely scientific and experimental work; and in it we find, not only

the original investigators, the compilers, and the mathematicians, but also those who have charge of the experimental and physical laboratories of the great railroads and industrial establishments of the country. These form a body of ever-increasing importance, not only in their number, but also in the value of their work, which is in a certain sense similar, or rather analogous, to that of the analytical chemist. Their duties are peculiar in this respect, that, as far as they are personally concerned, commercial considerations do not, at least to any great extent, enter into them; they have little or nothing to do with the management of men, nor with the question of the best utilization of their labor; they are rather critics of other men's work than directors of it. For example, they are not required to produce at a given cost a certain quality of iron or steel, but to determine the physical and chemical properties and the relative values of the different kinds of steel and iron that are produced; to decide whether a given specimen is what it pretends to be or not; to tell whether its qualities are such as to fit it for any special use. But their functions do not cease here. They discover, by experiment, new uses for old products and new products for old uses; they investigate scientifically the new problems that are constantly arising in the fields in which they are engaged, and which it would be impossible for engineers engaged in the practical direction of establishments of this kind to work out, without interfering very seriously with those important duties which require their attention at all times.

The second class, which is a very large and important one, includes those who formerly constituted almost the whole body of engineers, and who more nearly answer to the commonly received idea of the profession. The type of this class is the *chief engineer of a railroad;* he is the scientific adviser of the managers of the road. They decide what work is to be done or what it is advantageous to produce, what railroads it is commercially desirable to build; but it is his function to examine and advise them as to the various routes that may be adopted, giving in detail the particular advantages of each route, as to its cost of construction and of maintenance, and of the greater or less expense of working it; he is supposed to investigate and report upon the different systems of bridges, rails, ties, etc.

If the managers have decided to build a road or a furnace, or if it has been determined to open a mine, it becomes his duty to super-

vise the preparation of the plans and the laying out of the work; if the actual construction is given out by contract, to see that the terms of the contract are carried out strictly, that only as much money is paid therefor, at the times and under the conditions that were originally agreed upon, and that the material and work in all respects is of the class which it was decided that it should be. But if, as is sometimes the case, the work is not let by contract, but is built by the company themselves, his duties become still more onerous and complex. He must then see, not only that the work is properly done, but also that just wages are paid; that competent men are employed; that suitable materials are used; that they are properly utilized from a mechanical staindpoint; that the price paid for them is the lowest compatible with good quality, and that finally everything is done so as to produce the best result for the smallest amount of money. For this he needs not merely a broad and thorough technical education, but good common sense, a knowledge of men, and business experience.

The third class, which is of comparatively recent origin, is becoming more and more important, and promises in the future to relieve those of the second class from much of their uncongenial duties, and comprises what may be called business or contracting engineers. I may probably best make myself understood by an example. Twenty-five or thirty years ago, if a railroad company wanted to build a bridge, unless it was a very small one, the chief engineer would have the ground carefully surveyed and examined; would have plans prepared in his office; would buy the materials from different parties, and have them properly worked up and the bridge erected under his own supervision. Now, the case is different; he would practically do nothing, except in very rare instances, but ask for bids for a bridge to be built of a given height and span under certain specified conditions over a valley or river, which would be capable of sustaining a given moving load. He would, if his company were able to pay for it, have no trouble in having this done by contracting engineers for a lump sum, under a guarantee that it would be perfectly satisfactory, although each bidder would prepare his own plan for the structure. This applies not only to bridges, but to almost any other engineering work that is not of a very special character; in fact, it is not an uncommon thing for a contract to be made to construct and deliver a railroad, built and equipped in a specified manner for a certain

sum of money, or even for a certain amount of stock and bonds. Many of the blast furnaces recently erected by new companies have been built in this way. Some of the brightest minds in the profession are now engaged in this business, and it seems destined to become a more and more common way of doing work of this character. Where the contracting engineer is a man of ability and character it is a most satisfactory method, both to the man doing the work and the one paying for it. This change, which is gradually being made in the duties of the profession, attracted my attention some years ago, but of late it has been so marked that I have almost unconsciously been giving a great deal of thought to it. It seems to me that it is worthy of the careful consideration of all of us, whether we are teachers, consulting engineers, or men of business. If the fact be such as I have stated, if engineering be broadening and covering almost the whole field, from pure science to pure business; if two young men, who are members of the same class in a technical school, and following the same course of instruction, be destined to such different duties, though they may both become in name engineers, is it not time for us to pause to examine the whole field of technical education, to study carefully the mental requirements and training of those who are to devote themselves to each of these three branches of what is now called engineering? As we all know, there has been for the past ten or fifteen years a very active, vigorous, and interesting discussion of that most important subject, "technical education." Men of ability and of experience, who have given much time and thought to the question, differ as widely as they did ten years ago as to the proper relation of theory and practice in the training of the young engineer. They are not in accord as to whether a student should do practical work before, during, or after his collegiate course. There are many advocates of each plan, but among those who apparently have had the best opportunities of judging, there is, as yet, no agreement as to what advice should be given to a young man wishing to enter upon a technical career. No matter what plan may be suggested, there are always examples, both of the good and bad effects of adopting that system, which are constantly being brought forward. One of the most pleasant and hopeful features of the discussion, however, is the great interest that is felt in it by the older members of the profession, and the amount of time and thought that they are not only willing but anxious to give to it,

when we consider how little leisure they generally have for such work. However, notwithstanding the fact that so many able and educated minds, which have been trained to the most scientific and logical treatment of a vast range of subjects, have been so long trying to solve the problem, they seem yet as far as ever from coming to any agreement as to the proper relations of theory and practice in technical education. Like many of you, I have also given some attention to the question, and, although I cannot claim to have gone into it thoroughly and systematically, and consequently must submit what I have to say with diffidence, it has occurred to me that perhaps one of the causes of the difficulty of coming to a practical agreement as to the best course of study for a young man wishing to become an engineer, as has been done for those preparing themselves for the church, the bar, or medicine, is the fact that the field covered by the professions and pursuits now included by the term engineering, has become too great for any single course of study to be applicable to it. In every State in the Union there is practically a well-defined course of study, which must be followed by those who intend to become members of the bar, and an examination which at least claims to be similar in character, that each person must pass before he is admitted. There is little or no discussion as to whether some other system of education would be better. There are, of course, differences of opinion, as to the greater or less importance of some of the details of the student's work, but they are not such as attract any great attention. So with the church: each denomination has its own views as to the mental character of the candidates, and as to the manner in which they should be instructed; but practically, each sect is agreed as to the general principle upon which the studies of those who intend to enter the ministry should be conducted; so, in medicine, there is very little divergence of opinion as to the relation that the practical work in the dissecting-room, at the clinic, and in the hospital, should bear to the theoretical training of the lecture-room and the text-books. There are, of course, some changes in the methods of theoretical instruction, in which the more advanced schools have not been followed by the more conservative institutions, but they are rather questions of detail than of principle. They all agree as to the relation and character of the practical to the theoretical work, and as to the time in which the former should be done. But, when we come to the training of the

engineer, this general unanimity is no longer to be found. Is it because the study of engineering is of so recent a date that it has not had time to develop properly? This may be one reason, but it does not seem to me to be sufficient to account for the fact. The more I think of it, the more it seems to me that the great difficulty is, that the field now attempted to be covered by an engineering education is too vast to come within any one system of instruction. The state of affairs is, to a certain extent, similar to what would be the case if a number of clergymen, doctors, and lawyers should endeavor to lay out a course of study for students to follow in common, with success and profit, when a part of them (it would be impossible to determine beforehand which) were to devote themselves afterwards to the practice of the law, part to the practice of medicine, and part to the work of the church. Now, while such a plan would never be proposed, yet I feel satisfied that, if several thousand students were compelled to follow a course laid out in this way, there would always be among them a few, whose special aptitude for one or other of the professions would be so great that they would rise to eminence in their own specialty; for they would assimilate and profit in the highest degree by that portion of the instruction peculiarly suited to their turn of mind. Yet there is no doubt that a great part of the time and energy of the mass of the students would be wasted, and that the useful effect of their training, as a whole, would be very discouraging.

No one would, of course, suggest or consider such a plan, but a reference to it may be of use in enabling me to impress more strongly upon your attention the idea which has suggested itself to me, and which, I think, may possibly be worthy of the attention of those who are giving the subject of technical education the advantage of their experience, their training, and their thought; and I know that there are many in this Association to whom this is a subject of deep interest.

One of the most important duties, one of the greatest privileges of an educated, trained, thinking man, is that of preventing waste, whether it be of matter or force, whether the latter be physical or mental; and what more dreadful waste can there be than the misdirected energies of the young student, who has so little time at his disposal and so much to learn, before he is obliged to enter upon those active duties by which he must gain his daily bread? If he who makes two blades of grass grow where one grew before

deserves well of mankind, how much more he who aids in preventing the useless labor of sowing seeds that are likely to develop into worse than useless weeds!

If, as it seems probable, engineering is now becoming really three professions or callings, differing so widely from one another as to demand a special training for each, is it not, perhaps, possible that no one collegiate course will be suitable and advisable for all? Is not the question, at least worthy of thought and discussion? In the hope that you will deem it so, I submit it to you for your consideration.

ELECTRIC SIGNALING IN MINES.

BY E. Z. BURNS.

THE importance of hoisting ore from a mine with the least possible delay, and of lowering timber, machinery, etc., into the mine with promptness, renders some method of rapid signaling necessary. Among the rapid methods often used, a large number of mines employ a system of electric bells. In many cases this method has been adopted, not so much for any reason of superior excellence or economy, but because the person or persons having the matter in charge accepted the first method suggested, without making any investigation of its merits. It therefore often happens, that an engineer, having no experience in the management of batteries or electrical apparatus, is called upon either to put a system of bells in operation, or to take charge of one already established. For those who are placed in such circumstances a few suggestions may prove of interest and value.

There are two kinds of batteries in common use, the crow-foot form of the gravity battery, and the Leclanché battery, either of which gives good results. Having decided upon the kind of battery to be used, the next step should be to ascertain the number of cells required. The number may be determined near enough for practical purposes as follows: Find the maximum length of wire over which the current will at any time pass, and the total number of bells, with annunciator, to be operated simultaneously.

With these data the external resistance may be determined, and the number of cells may be calculated from the following formula:

$$N = \frac{C\,(R + R')}{E - Cr}$$

in which,

N = Required number of cells.
C = Strength of current in amperes.
R = Resistance of wires in ohms.
R' = Resistance of bells and annunciator in ohms.
E = Electromotive force of one cell.
r = Internal resistance of one cell.

Of these quantities the value of C is assumed, R depends on the size of wire, and, the length being known, may be calculated, R' may be obtained from the manufacturers, while E and r may be obtained from some book on the subject. It will be necessary to order a slight excess over the value obtained for N, to provide for breakage, the extension of the line, etc.

The cells should be placed in a cool room, especially if the Leclanché form is used, and should be examined every two or three days. It should be remembered that very much depends upon the care given to the battery. If the Crow-foot form is used the zincs should be closely examined, and cleaned whenever they present a rough, dirty appearance. Care should also be taken that the blue color of the liquid does not rise more than half way to the zincs. When the Leclanché battery is used, the porous cells, if these are employed, should be quite carefully examined from day to day, and as soon as any tendency of the manganese to harden is shown, it should be thoroughly washed with hot water, and a jet of steam if it can be obtained. A more convenient form of the Leclanché battery is where a plate of carbon is inserted between prisms of carbon and peroxide of manganese.

Little need be said concerning the surface wires. They are quite often strung along the trestle from the engine-house to the shaft-house. If possible, they should be introduced through the gable end of a building, otherwise, in winter, the eaves may drip upon them and form a short circuit by means of icicles.

There are many difficulties to be encountered in putting wires underground, and making them work successfully. Acid water and acid vapor seem to defy all attempts to perfectly insulate the

wires. For instance, a cable containing three wires was put down one of the shafts of the Lake Angeline Iron Mine, during the winter of 1886–87. As seen in Fig. 1, this cable was thoroughly insulated. Each wire is covered with rubber, and around all the wires are two layers of fibre closely wound and tarred, and a third layer on the outside, of woven material well impregnated with white lead. In order to better protect this cable from the water and vapor of the mine, it was placed in a scantling which had been grooved out for that purpose. An excess of tar was put into this groove, so that when the cable was placed in position and the cover nailed on all cracks and crevices were filled with the expressed tar. During November, 1887, this cable was taken out. It had been doing poor service for some time, and with reason, for the insulation was found in some places entirely destroyed, and in other places saturated with water. This result seems to indicate the course that should be pursued; that is, that while the wires should be as well insulated individually as possible, they should also be so arranged as to make them readily accessible for examination and cleaning. Following this course, the scheme shown in Fig. 2 was devised, and works very well. The wire used has nothing but a rubber insulation. Three grooves are cut in the timber, which needs to be only about one inch thick. After the wires are put in place a half-inch board is nailed or screwed on for a cover.

In connecting the battery and bells with the wires, there are a few points that may prove somewhat puzzling. It is often quite necessary not only that the bell should ring in the engine-house, but that one at the surface should ring at the same time, and thus give notice to the surface-trammers when a car is being hoisted. In Fig. 3, let *A* represent the bells in the engine-house, *C* the bell or bells on the surface at the mouth of the shaft, and *D* the bell on any level. Now, suppose the push-button No. 1–D to be pressed, thus completing the circuit on the level, and suppose the current to flow in the direction of the arrow at *a*. It will be seen under this supposition, that the current must first flow through the electro-magnet of No. 1–A, thus ringing the engine-house bell, then back along *a'* and down *a''* to the level. It now passes through the connection made by the push-button, and, ringing the bell on the level, flows back toward the battery along the return-wire *d*. When it reaches the surface it passes through the electro-

magnet of that bell which it rings, and then passes on up the wire to the battery B.

The illustration also shows the method of connecting two or more push-buttons on the level with one bell, so as to ring a bell in the engine-house corresponding to the push-button used. This

FIG. 1.

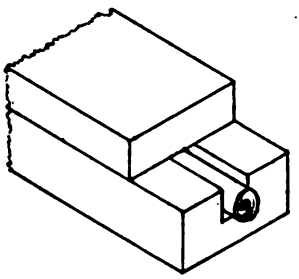
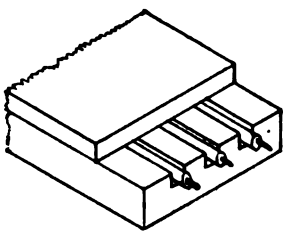


FIG. 2.



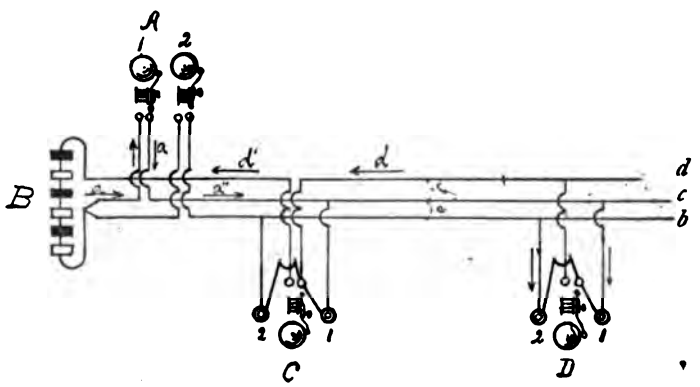


FIG. 3.

lessens considerably the first cost of the plant, since there is saved the expense of one bell on each level for every additional line of signals except the first.

A cross in the wires is usually detected: first, by a tendency of the tongue of the bell to remain down, especially after ringing; second, by the annunciator giving a constant indication that the bell has been rung; third, by the ringing of all the bells connected with the same common wire when any one of the number is rung. The reason for these indications will be readily seen by examining Fig. 3. If there is a cross, for instance, at *e* between the wires

b and *c*, then, when the push-button 2–D is pressed down, the current may ring either the bell 2–A or 1–A. If there is a cross at *f* between the wires *c* and *d*, the current will flow all the time, and the annunciator will give a constant indication. In this case, too, where there is a cross at *f*, the tongue of the bell will either remain against the electro-magnet, or else, after ringing, will come back very sluggishly to its place.

The first thing to be done in case of a cross, is to disconnect the common wire *d* at the mouth of the shaft. There are two reasons for this: first, to preserve the strength of the battery; second, to discover the place of the cross. If the cross is in the underground wires the surface bells will then ring properly. When it is found that the cross is in the underground wires, connect the wires at the surface, and disconnect them below the first level, and in this way find if the bells ring properly as far as the first level. Proceed in this way till the cross is located somewhere between two levels, then examine carefully the wires between these two levels till the place where the cross occurs is found. Very often the cross occurs in the box containing the bell, owing to a careless arrangement of the wires, especially when one bell is connected with two or more push-buttons, as seen in Fig. 3.

The underground bells are quite often located where water is constantly dripping, and where acid vapors are making their way to the shaft, and for this reason, as well as to prevent the miners from meddling with them, they should be placed in as nearly water-tight and air-tight boxes as is practicable. These boxes are usually of wood, with nothing but the push-button appearing on the outside. In especially wet places it is well to have a slanting roof over each box, and extending at least 6 inches beyond the edges of the box.

The average cost of putting electric bells in a mine, with the expense of keeping them in running order, is probably greater than some other methods of signaling; but there is no doubt that, once established in a mine, they may, with a little care, be made to work successfully.

ROSENBUSCH'S MICROSCOPIC PHYSIOGRAPHY OF THE MASSIVE ROCKS.*

WITH the beginning of the new year has appeared the second part of this monumental work, which has been impatiently awaited by the petrographers of the world, and which gives a most accurate and exhaustive *résumé* of the sum of petrographical knowledge up to the date of its issue. Though an author to be thoroughly understood must be studied in his own language, a translation of the introduction and those portions relating to the general system of classification are given in the following pages, in order that those who do not read German with ease may have an opportunity of acquainting themselves with the philosophical principles which Prof. Rosenbusch's wide experience has led him to adopt and enunciate.

A complete translation of this book, and of the preceding volume on the Microscopic Physiography of the Petrographically Important Minerals, from the experienced pen of Mr. Joseph P. Iddings of the United States Geological Survey, will soon be issued by the press of John Wiley & Sons.

INTRODUCTION.

The microscopic physiography of rocks assumes the task of stating the manner in which they are mineralogically composed of certain essential and a greater number of accessory constituents which sometimes belong to a definite mineral species, and sometimes represent a partially or wholly structureless substance, unrecognizable or nearly so, and chemically formed in accordance with stoichiometric proportions, and of discussing the way and manner in which these different components or rock elements bind themselves to the rock body.

The following work does not concern itself with all rocks, but only with a part of them. Since a rock is not a mineralogical but, as Lossen in particular has correctly and forcibly shown, a geological individual, not merely a mineral aggregate, but eminently a geological body, we must at first consider all kinds of rocks accord-

* Mikroskopische Physiographie der Massigen Gesteine, von H. Rosenbusch. Stuttgart, 1887. pp. 877. Pl. vi. Translated for SCHOOL OF MINES QUARTERLY by F. J. H. Merrill.

ing to the place which they receive in the structure of the solid crust of the earth.

The dignity of the name rock does not belong to every indiscriminate portion of our earth's crust. Only those inorganic masses which lead an independent existence and are to be regarded as integral parts of the earth's crust, are here comprised as rocks, and not those mineral aggregates, mainly insignificant as to quantity, which occur only as subordinate, relatively unessentiall, and incidenta layers and segregations. This limitation of a rock as an integral part of the geological whole, involves the existence in it, as to its external appearance and relations to other rocks, of a certain regularity, so that it appears as a stratum, dike, neck, etc. According to this kind of geological entity, we divide all rocks into two grand divisions. First, the stratified rocks, which clearly bear, in the manner in which they lie on one another as parallel beds, the character of successive deposits of substances mechanically suspended or chemically dissolved in a liquid. The rocks of the second group, on the other hand, are characterized by their forms and the manner in which they penetrate strata, as the result of a more or less sudden and abnormal eruptive action. In antithesis to the strata they present simple masses and are therefore called massive or eruptive rocks.

Up to a certain point, the tuffs and loose ejected matter of our recent or earlier volcanoes, are intermediate between the stratified and massive rocks. They have, in common with the first, the character of their present local appearance; with the latter, in part positively, in part very probably, they have a common origin.

In this book the attempt is made to give a microscopic physiography of massive rocks and of the loose ejecta of volcanoes, as well as of those tuffs which evidently or probably formerly represented a loose ejected material. Since the massivé rocks in many cases have modified the mineralogical composition and the structure of the stratified members of the earth's crust, or other massive rocks which are in contact with them, it seems advisable to review these phenomena which we designate contact-phenomena.

The synoptical character of the presentation requires the union and arrangement in groups of the eruptive masses, which differ greatly in geological form, age, structure, and mineralogical as well as chemical composition. Such an arrangement, carried out according to definite principles, is called a petrographic system of the eruptive rocks.

Such a system would be more natural, that is to say, more perfect, the more equally it were adjusted to the above named relations; it would be properly designated as a natural system when the causal relation of the foregoing distinct groups found an adequate expression in it, so far as such a thing actually exists. The views upon the question as to which of the foregoing groups are the conditioning and which the conditioned, have changed very frequently during the development of petrographic knowledge, and different investigators have held different views at the same time.

The immense mass of material which the diligent work of numerous investigators during the past ten years has gathered together, enables us to know with great certainty, that the conditions of *geological occurrence* almost exclusively determine the *structure* of an eruptive rock. Eruptive masses of the same chemical and mineral composition possess quite different structure according as they have flowed over the surface of the earth in the form of lava, or developed into rocks in deeper regions of the solid crust of the earth. It is, however, self-evident, that not merely the mathematical form of the rock space makes a certain structure necessary, but rather the temperature and pressure during the rock-making, which are conditioned by the local position (according to depth). This clearly follows from the fact, that we occasionally find on the periphery of plutonic rocks the structural peculiarities characteristic of effusive rocks, while on the other hand, in the centre of effusive rocks the structure of plutonic rocks not unfrequently prevails.

A dependence of the chemical and mineralogical composition of an eruptive rock upon its geological conditions of occurrence does not appear to exist in full strictness and generality. It cannot well be disputed, however, that certain definite relations are always present up to a certain point, when, for example, it is remembered that in all groups of rocks of like mineralogical composition the effusive volcanic masses are always richer in silica and alkalies and poorer in dyad metals than the intrusive plutonic rocks. In like manner one is compelled to accept a similar dependence through the association of certain components with definite geological relations, as well as by the constant habitual differences of other components according to the mode of occurrence of the rock to which they belong. For example, we find muscovite only in plutonic and never in volcanic rocks; leucite, on the other hand, only in the neo-volcanic rocks; rhombic pyroxenes, in part, also amphiboles,

quartz, and many other minerals, possess an entirely different habit in the plutonic rocks on the one hand, and in the palæo- and neo-volcanic rocks on the other. It is especially indicative of a causal relation between geological position and mineralogical composition, that the laws of association for the rock-forming silicates are quite different in the eruptive masses from those which prevail in the crystalline schists.

The chemical composition of a rock is evidently of the greatest importance in conditioning its mineralogical development. Although only the first steps have been made toward the knowledge of the laws which formulate the chemical composition of the rock-components as a function of that of the rock itself, still the general dependence of the mineralogical upon the chemical composition of the eruptive formations is surely established to such an extent, that at least in general from the analysis of a rock-mass its mineralogical composition may be deduced, and *vice versa.* The chemical composition influences the structure only so far as certain structural forms of volcanic rock appear to be associated with a certain acidity of the rock (for instance in the case of the granophyric and microfelsitic structures).

A greater importance has hitherto been ascribed to *geological age* in determining the structural and mineralogical formation of an eruptive rock than, in fact, belongs to it. That mineralogical composition is independent of geological age can scarcely be doubted nowadays. The influence which the latter appears to possess over the structure of the eruptive rocks can be explained with greater probability, by the fact that certain geological forms which determine structure, are in general associated with a certain geological age. Plutonic rocks can only become accessible to us for observation through extensive denudation, and this in turn presupposes certain dynamic processes and an erosion, of which the completion is dependent upon a long lapse of geological time. We have the direct indication that the structure of the eruptive rock is independent of its geological age, in the circumstance that the structural forms characteristic of very old plutonic rocks, under proper conditions also occur in palæo- and neo-volcanic rocks, and *vice versa.* We must, however, of course not lose sight of the fact that, for example, effusive masses of upper palæozoic or lower mesozoic age, in contrast with those of tertiary or recent age, present certain differences of structure which are appreciably, if

indeed not generally distributed, and which perhaps may be secondary. In like manner, it cannot be gainsaid that a lava which has flowed out during a period of our earth's history in which our atmosphere was much heavier, and the temperature of the earth's crust was generally much higher, might possibly assume the structure of an intrusive rock of a much later geological epoch.

From the indicated relations between the geological form, structure, chemical and mineralogical composition, as well as the geological age of eruptive rocks, it follows that a natural system of them must primarily emphasize the geological form as determining structure and mineral constitution; in the second place must be considered the chemical and the mineralogical composition which is essentially dependent upon it; finally, the geological age.

Those changes in the structure and mineralogical composition of an eruptive rock which it experiences after its solidification through secondary processes, weathering, decomposition, contact effects, or geodynamic processes cannot pretend to the importance of a classification.

According to their geological form, two principal groups may be distinguished. Among the eruptive or massive rocks those belonging to the first group rose up from the interior of the earth through fissures, and filled hollow, irregular cavities, *without ever reaching the surface of the earth*, or penetrated from the fissures into seams in the strata and geotectonic cleavage planes between the masses of sediment.

These eruptives consequently form necks, dikes, intrusive beds and bedded dikes; they bear no necessary relation to volcanoes and craters, and evidently can never be accompanied by tuffs (loose ejected material). They may be called *plutonic rocks*, or *intrusive rocks* (*Tiefengesteine*). The formation of the plutonic rocks accessible to us for observation has, in accordance with the foregoing principles, taken place chiefly in remote geological periods. They have first been laid bare by erosion or mountain building agencies.

The rocks belonging to the second group of eruptive rocks likewise penetrated upwards from the interior of the earth through fissures, but reached the surface of the earth and poured over it subaerially or under water, in part welling forth directly from the fissures, in part from true volcanoes built over certain points in the fissures.

The geological form of these eruptives is that of streams, sheets and domes. They are not necessarily, but very frequently, ac-

companied by tuffs. We designate these in general as *volcanic rocks* or *effusive rocks* (*Ergussgesteine*). So far as these do not possess too great a geological age their relation to volcanoes can often be ascertained with complete certainty; with increasing geological age these relations are very rapidly effaced. The characteristic volcanic forms are flat, and, geologically speaking, rather ephemeral formations, and also the tuffs which are so characteristic of a volcanic origin are easily removed by denudation. Accordingly the effusive masses of the tertiary and quaternary, which are often evidently connected with volcanoes, may be separated as *neovolcanic*, from the pretertiary or *palæovolcanic* eruptives.

Evidently every sheet and every outflow of an effusive rock, and every neck and every bed of an intrusive rock, presents a rock dike —the filling of the channel through which the eruptive masses came up out of the interior of the earth. Therefore, we shall meet with the dike form, as well in connection with the plutonic as with the volcanic rocks. There is, however, a certain class of eruptive rocks which so far has never been met with in other than dike form, or only very exceptionally. These may be designated as simply *dike rocks*. We know no tuffs of these; this circumstance, as well as certain structural peculiarities, associate the dike rocks with the plutonic. On the other hand, there occur in them some forms of structure which we otherwise only observe in volcanic rocks. The dike rocks have, therefore, an intermediate place between the two great groups of the plutonic and volcanic eruptives. An eruptive mass, penetrating from the interior of the earth to a volcanic vent in consequence of geodynamic processes, when we consider the whole order of the eruption to its end, will have formed on the surface of the earth volcanic rocks and loose ejectamenta, while at greater or less depths it must have produced rocks of plutonic habit. From this it follows that the peculiarities of the plutonic and volcanic rock types are not necessarily functions of geological age, but in every case functions of depth (*Tiefenfunctionen*), that is to say, functions of pressure and temperature. The peculiar differences of these two chief types of eruptives are based upon the indications of bare facts of experience; they are conditioned, necessary, and must consequently be susceptible of explanation and derivation.

The order of the eruptive rocks in this work is the following:

I. Class—Plutonic rocks.
II. Class—Dike rocks.
III. Class—Volcanic rocks and their tuffs.

I. Class—Plutonic Rocks.

In the history of an eruptive or massive rock, three periods of distinct development may be differentiated. The first embraces the time in which the substance of the rock in the deepest cavities of our globe formed itself from a metallic mixture into a molten silicate solution of higher temperature, through oxidation and absorption of water. Petrography has thus far found no means of obtaining knowledge concerning this division, which we shall call the prehistoric period of the rock, by direct observation of any terrestrial rock species. Information about the processes which have occurred in this period of time can only be expected from the study of meteorites, from experiment, and chemico-physical speculation. The second period embraces the time of the crystalline development of the fluid silicate magma within the earth, and may, therefore, be called the *intra-telluric* period. The third and last division in the building of a rock begins with the exit of the same upon the surface of the earth, and closes with its complete solidification. During this *effusion period* the crystallization is essentially completed with reference to the congelation of the so-called ground mass. Upon these three periods of rock-building proper follows then, finally, the time of the most diverse chemical and dynamical changes, which we will call the metasomatic period. If we disregard the very youngest lavas, all other eruptive rocks occur in a condition of more or less advanced metasomatosis. Out of this we must reconstruct the normal condition after complete formation, and this we ordinarily take as the basis of the description and definition.

From the geological form of the plutonic rocks it follows that they have not been subjected to the third period of a normal and complete eruptive rock development. The solidification of the same took place completely in the depths of the earth, that is to say, under high pressure and at a high temperature, but especially under physical conditions which, according to the very nature of the thing, could only change slowly and uniformly. The process is, consequently, essentially like that of the crystallization of a mixed solution, and as different as possible from that of a rapid congelation caused by loss of heat. To this correspond exactly the real

relations to be observed. We meet nowhere amorphous, glassy substances, that is, structureless congealed remnants of the rock magma which have not reached a crystalline form, and the succession of the mineral separations follows chemical laws exclusively. Consequently a great uniformity generally prevails with reference to the structure and universal composition throughout the whole mass. Exceptions to this rule usually occur only on the periphery, where through the contact with the adjacent rock varying structural conditions must easily, almost necessarily, have prevailed.

That structural form of a massive or eruptive rock in which it consists of mineral individuals clearly crystalline if not always crystallographically bounded, will be called *Holocrystalline* structure, its opposite, the *Amorphous* structure, would be present when the rock-body throughout its whole extent consisted of an "uncrystalline," structureless, "solidification product" of a fluid. If an eruptive rock is composed of a mixture of crystalline mineral individuals and hyaline substance, the structure may be designated as *Hypocrystalline*, without reference to the relative quantity of these two components.

The structure of plutonic rocks, excluding abnormally developed peripheral portions, is *holocrystalline*. Since, however, in effusive and dike rocks, a holocrystalline structure occurs widely distributed, the question arises wherein the holocrystalline structure of the plutonic rocks differs from the same structure in effusive and dike rocks. We can divide the manifold components of eruptive rocks into four groups:

1. The ores and accessory components, Magnetite, Ilmenite, Hematite, Apatite, Zircon, Titanite, etc.

2. The iron-magnesia silicates, Olivine, Micas, Amphiboles, Pyroxenes.

3. The feldspathic components, Feldspars proper, Nepheline, Leucite, Melilite, Sodalite, Haüyne.

4. Free Silica.

In all plutonic rocks the development of these components occurs so that the formation of any one of them was continuous, having taken place in a single period of time, which the crystallization of the other components preceded or followed. Consequently,—and this is the most important structural characteristic of plutonic in distinction from effusive rocks—in general there is one generation of each component.

The formation-periods of the different components followed succes-

Class II.—Dike Rocks.

In the group of the dike rocks are here included only those eruptive masses which, as independent geological bodies, according to our present knowledge appear exclusively in typical dike form, although many of them also occur more or less frequently as facies, in part of plutonic, in part of volcanic rocks. Among these typical dike rocks we find, again disregarding a few exceptions, the characteristic mineral combinations by which the plutonic rocks are distinguished from one another and arranged in families. Yet it must be emphasized that, on the one hand, no dike rock, as here defined, occurs which has the mineralogical characteristics of the gabbro, diabase, peridotite, or theralite family; while, on the other hand, among the dike rocks also, individuals are found of which the characteristic mineral combination does not occur among the plutonic rocks.

According to their mineralogical and chemical composition, the dike rocks may be arranged in a granitic, a syenitic and a dioritic group. It deserves to be mentioned, however, that in close geological relation with the elæolite syenites is a very varied dike-formation in the Serra de Monchique and in Brazil, further investigation of which perhaps may lead to the establishment of an additional group. The members of this dike-formation show so great an analogy to the phonolites (and tephrites), and consequently to the effusive forms of the elæolite syenites that an exact differentiation is difficult. An independent elæolite-syenitic dike-formation is only known feebly developed in the Fassathal. The dike form of the diabase, gabbro and peridotite families corresponds so completely with either their plutonic form or their effusive equivalents, that a differentiation does not seem possible.

It is evident, from the nature of the case, that the dike rocks in general do not possess the same uniformity of habit and structure which usually characterizes the plutonic rocks. The multifarious character of the conditions of crystalline development conditioned by their geological mode of occurrence is too great to permit of this uniformity, nevertheless it is unmistakable, that according to habit and structure, there are three recognizable types more or less independent of mineralogical composition: First, a *granitic*, which up to the present time is only known among the most acid representatives (orthoclase quartz rocks), but probably will be known among the elæolite syenites; second, a *granite-porphyritic*, which

has appeared in every group that can be established according to mineralogical composition; and third, a *lamprophyric*, which appears to lack the most acid members of the class of dike rocks. These three types are also well differentiated macroscopically and form natural groups. The components of the rocks of the first type (aplites or muscovite granites) are of small dimensions, and are arranged in a manner similar to that of the hypidiomorphic granular structure of the plutonic rocks. The individuals of the second type are seen by the unaided eye to possess a habit which is clearly porphyritic, the disseminated crystals and the ground mass are for the most part sharply differentiated. The crystals are large and belong preëminently to the feldspars. The ground mass, and consequently the whole rock, has for the most part clear colors. Here belong the *granite-porphyries*, the *syenite-porphyries*, the *elæolite-porphyries* and the *diorite-porphyrites* so far as they are dike rocks; their ground masses are holocrystalline, and as such for the most part, indeed, may be recognized with the eye and the hand lens. The lamprophyr type is likewise preëminently porphyritic, yet the rocks often possess macroscopically an almost aphanitic appearance. Microscopically, the structure is granular, the colors are gray to black, and the disseminated crystals are usually small and belong rather to the iron and magnesia minerals. In this group belong the *minettes*, *kersantites*, and related rocks.

(To be continued.)

THE CALCULATION OF CHARGE FOR LEAD FURNACES.

BY EDGAR L. NEWHOUSE, E.M.

IN the *Engineering and Mining Journal* of August 13, 1887, is an article on "Calculation of Slag Components," by Mr. George Murray. To an experienced metallurgist the problem is sufficiently demonstrated; but to one unaccustomed to the calculation of charges it is apt to present some difficulties. I have, therefore, with Mr. Murray's permission, undertaken to give a more thorough explanation than he thought necessary; so that one possessing but a limited practical knowledge of lead metallurgy may, with the requisite analyses, make a correct charge.

The first thing is to select a suitable and economical slag. This will depend entirely on the character of the ores obtainable by the smelter, the object being to make them as nearly self-fluxing as possible. Suppose that to be

SiO_2 — 30 per cent.
FeO — 40 per cent., or Fe = $\frac{7}{9}$ of 40 per cent. = 31.11 per cent.
CaO — 20 per cent.

which we know to be a good slag.

In this the SiO_2 components multiplied by 1.037 (31.11 ÷ 30) = Fe components.

Also, the CaO components multiplied by 1.555 (31.11 ÷ 20) = Fe components.

The analyses of the ores which are to enter the charge are

	SiO_2.	Fe.	CaO.	ZnO.	BaO.
No. 1.—Siliceous, .	53.0	10.3	4.5	1.8	3.6
No. 2.—Lead carbonate,	15.4	24.0	3.1	5.4	5.3
No. 3.—Flue dust, .	22.0	16.0	5.3	0.8	0.4

The ZnO and BaO, being earthy bases, may be counted in with the CaO.

$$ZnO \times .7 = CaO; \text{ also } BaO \times .4 = CaO.$$

Therefore the analyses of the ores may be written,

	SiO_2.	Fe.	CaO.
No. 1, ...	53.0	10.3	7.2
No. 2, ...	15.4	24.0	9.0
No. 3, ...	22.0	16.0	6.0

The lime-rock contains 50 per cent. CaO, and 3 per cent. SiO_2. Changing these to an iron basis,

50 per cent. CaO × 1.555 = 0.775 Fe.
3 per cent. SiO_2 × 1.037 = 0.3111 Fe.

250 lbs. of coke are used, having 13 per cent. of SiO_2, to flux which, requires 55 lbs. of iron ore and 45 lbs. of lime.

As there is some sulphur in the ore, 25 lbs. of iron ore are allowed for matte.

The total weight of charge is 1430 lbs.

Iron ore—55 lbs. for SiO_2 in coke and 25 lbs. for matte, .	= 80 lbs.
Limestone—for SiO_2 in coke, ...	= 45 lbs.
Old furnace cleanings—self-fluxing, ...	= 50 lbs.
Slag, ...	= 200 lbs.
	375 lbs.

This substracted from the weight of the whole charge (1430—375) leaves 1055 lbs., to be made up of ore lots Nos. 1, 2, and 3, and limestone, so as to form a 30—40—20 slag.

* $FeO = \frac{a}{c} SiO_2$ (1). $\qquad FeO = \frac{a}{b} CaO$ (2).

a denotes per cent. Fe = metallic bases.
b " per cent. CaO = earthy bases.
c " per cent. SiO_2 = siliceous bases.

On looking at the analyses of the ores, we see that No. 2 is the only one containing an excess of iron; consequently, considerable more of it must be used than of the others, so as to allow for the excess of SiO_2 in Nos. 1 and 3.

Let us assume the correct proportions to be *about* 100 lbs. of No. 1, 800 lbs. of No. 2, and 100 lbs. of No. 3.

No.	Per cent. SiO_2.	Per cent. Fe.	Per cent. CaO.	Assum.	lbs. SiO_2.	lbs. Fe.	lbs. CaO.
1	53.0	10.3	7.2	100 lbs.	53.0	10.3	7.2
2	15.4	24.0	9.0	800 lbs.	123.2	192.0	72.0
3	22.0	16.0	6.0	100 lbs.	22.0	16.0	6.0
				1000 lbs.	198.2	218.3	85.2

If we take 100 lbs. of No. 1, we have,

53 lbs. $SiO_2 \times 1.037 = 54.96$ lbs. reduced to an Fe standard.
10.3 lbs. Fe $\times$ 1.00 = 10.3 lbs. reduced to an Fe standard.
7.2 lbs. CaO $\times$ 1.555 = 11.2 lbs. reduced to an Fe standard.

Let x = number of lbs. of mixture of the three lots.

Let y = number of lbs. of limestone.

The SiO_2 in $x = 198.2$ lbs. $\times$ 1.037 = 205.5 lbs. in 1000 = $.2055\,x$. Substituting in equation (1), putting the siliceous members on one side, the metallic on the other; $54.96 + .2055\,x + .03\,y$ (SiO_2 in limestone) = $.2183\,x + 10.3$ (3).

The CaO in $x = 85.2$ lbs. $\times$ 1.555 = 132.5 lbs.in 1000 = $.1325\,x$. Substituting in equation (2), putting the lime members on one side, the metallic on the other. $11.2 + .1325\,x + 0.777\,y$ (CaO in limestone) = $.2183\,x + 10.3$ (4).

From (3) and (4)

$x = 4704$ $\qquad$ $y = 518$

or

4704 of mixture of three lots.
518 of limestone.
100 of ore No. 1.

5322

* "Calculation of Slag Components."—George Murray, Eng. and Mining Journal, August 13, 1887.

There are to be, however, but 1055 lbs. added to the charge.

$$\therefore \quad 1055 \div 5322 = 0.198$$

and

4704 lbs. × 0.198 = 931 lbs. of *x*.
518 lbs. × 0.198 = 103 lbs. of limestone.
100 lbs. × 0.198 = 20 lbs. of No. 1.

Dividing *x*, as in the assumed ratio,

931 lbs. × .100 = 93 lbs. No. 1.
931 lbs. × .800 = 745 lbs. No. 2.
931 lbs. × .100 = 93 lbs. No. 3.

The ore scales weigh only to 5 lbs.
The charge would, therefore, consist of,

No. 1.—Siliceous ore—95 lbs. + 20 lbs., . . .	= 115 lbs.
No. 2.—Carbonate ore, ...	= 745 lbs.
No. 3.—Flue dust, ...	= 90 lbs.
Furnace Cleanings, ...	= 50 lbs.
Limestone—103 lbs. − 45 lbs., ...	= 150 lbs.
Iron ore—25 lbs. + 55 lbs.	= 80 lbs.
Slag, ...	= 200 lbs.
Total, ...	= 1430 lbs.

On multiplying the components of the three ores taken by the number of lbs. of each found, and adding to the lime columns the 103 lbs. of lime-rock used, we have,

SiO_2,	32.95	Reducing to 90 per cent.	29.66
FeO,	44.55		40.10
CaO,	22.47		20 22
	99.97		89.98

Thus proving the correctness of the formula deduced by Mr. Murray.

Other slags should multiply their constituents, by figures depending upon the relations of the SiO_2, CaO, and FeO in the standard slag.

Thus in SiO_2 33, FeO 33, CaO 23,

Multiply SiO_2 by 0.777 = Fe } ⅓ of 33 = 25.662 ÷ 33 = 0.777
and CaO by 1.11 = Fe } ⅓ of 33 = 25.662 ÷ 23 = 1.11

ADDITIONS TO THE COLUMBIA COLLEGE LIBRARY IN THE DEPARTMENT OF NATURAL SCIENCE, USEFUL AND FINE ARTS. APRIL—MAY, 1888.*

I. ASTRONOMY.

OLIVER, J. A. W.—Astronomy for Amateurs. 12mo. London. 1888.
KIRKWOOD, D.—Comets and Meteors. 12mo. Philadelphia. 1873.
BLAKE, JOHN F.—Astronomical Myths. 12mo. London. 1877.
PROCTOR, R. A.—Universe of Stars. 2d ed. 8vo. London. 1878.

II. BOTANY AND ZOOLOGY.

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CONGRES INTERNATIONALE de Botanique d'Anvers. 8vo. 1887. (*Gift of Dr. N. L. Britton.*)
BRENDEL, F.—Flora Peoriana. 8vo. Peoria. 1887. (*Gift of Dr. N. L. Britton.*)
UNDERWOOD, L. M.—Our Native Ferns. 12mo. New York. 1888. (*Gift of Dr. N. L. Britton.*)
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MACLOSKIE, G.—Elementary Botany. 12mo. New York. 1887. (*Gift of Dr. L. N. Britton.*)
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SCHRENK, C.—Enumeratio Plantarum Novarum. 8vo. Pettopoli. 1841.
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III. CHEMISTRY.

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THORPE, T. E.—Quantitative Chemical Analysis. 12mo. New York. 1887.

* Reader's tickets can be obtained without difficulty by those wishing to refer to books in the library.

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IV. ENGINEERING.

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JICINSKY, W.—Katechism der Grubenerhaltung. 8vo. 1876.
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MOISSENET, M. L.—De L'Extraction dans les Mines du Cornwall. 8vo. Paris. 1862.
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VI. MATHEMATICS.

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WIETLISBACH, V.—Die Technik des Fernsprechwesens. 12mo. Wien. 1886.
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GRANFELD, A. E.—Die Mehrfach-telegraphie. 12mo. Wien. 1885.
KRUSS, H.—Die Elektro-technische Photometrie. 12mo. Wien. 1886.
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X. MISCELLANEOUS.

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BIZZOZERO, G.—Manuel de Microscopie Clinique. 8vo. Paris. 1885.
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RAMSAY, A.—Bibliography—Guide and Index to Climate. 8vo. London. 1884.
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PROFESSIONAL NOTES AND ABSTRACTS.

New York City Water Supply.

At this time, when New York City is engaged in constructing its new aqueduct on a scale that few appreciate who are not engaged on the work, it may be interesting to glance backward at the condition of its water supply in 1838. Such a glimpse is afforded in a "Sketch of Civil Engineering in North America," written by the Scotch engineer, David Stevenson, and published in the year mentioned.

"The only supply of water which the inhabitants of New York at present enjoy, is obtained from wells sunk in different parts of the town. The water is raised from these wells by steam power to an elevated reservoir, and thence distributed in pipes to different parts of the town. Some of the wells in New York belong to the Manhattan Water Company and some to the Corporation. One well belonging to the Corporation is 113 feet in depth. For the purpose of collecting water there are three horizontal passages leading from the bottom of the well, which measure 4 feet in width, and 6 feet in height; two of them are 75, and the third is 100 feet in length. This well cost about $57,500, and yields 21,000 gallons in 24 hours. This mode of collecting water in subterraneous galleries has been successfully practiced in this country on a great scale, at the water-works of Liverpool, by Mr. Grahame, the engineer to the Harrington Water Company. The supply at New York

is far from being adequate to the wants of the inhabitants, and the water in most of the wells being hard and brackish, is not suitable for domestic purposes.

"New York is built on a flat island, which is nearly surrounded by salt water, so that the method which has been resorted to for the supply of Philadelphia and most other towns in the United States is altogether impracticable in that situation.

"Many plans have been proposed, and among others that of throwing a dam across the Hudson, so as to exclude the salt water; but as a free passage, by means of locks, must be preserved for the numerous vessels which navigate the river, the success of such a plan seems very doubtful.

"Many engineers in the United States of great reputation have made surveys of the country in the neighborhood of New York, in order to devise a plan for the supply of the city with water, and they have proposed to effect this object, so important to its inhabitants, by conveying the water of the river Croton in a tunnel to New York. The point from which the water is intended to be withdrawn is about 30 miles distant from the city. The estimate for the entire execution of the work is upwards of $5,000,000." * *

Advice to Young Engineers:

It is an uncertain, and yet very important period in the life of one devoting himself to the profession of engineering, when he graduates from the technical institution and is sent out to do for himself. He leaves the guidance of the school, yet his training is not finished, in fact, is scarcely started, and it is in not fully realizing this most positive and most important fact that his greatest danger lies.

The tendency is to misapprehend the power that a college training, however thorough, can give to the brightest student; and, although some natures are constructed in such a timid mould that they lack the confidence necessary to push themselves to the extent that their capacities warrant, yet the tendency is far more prevalent for the young graduate to do himself actual injury, and delay his progress, because of an overestimate of his value to the world as a working force, as a practical engineer.

Not for one moment should it be thought that a study of engineering is of little value, but it is only one part of the complete result desired. It must be mated with actual experience in field and office. Together they make a powerful team; singly, they find the load a heavy one, and the road difficult.

Many a young graduate, full of energy, and possibly better supplied with conceit than a knowledge of the facts alluded to, erects a large gilt sign on a busy thoroughfare, and advertises himself as a "Consulting Engineer." He might far better nail his shingle to some dry stump in the back-woods, and set fire to it on the first opportunity his business engagements would permit. The little brook that starts far up on the water-shed, and is contented to flow along channels that custom and nature have provided, presently finds itself a stream that gives life to vegetation, blessing man as it passes in refreshing flow, and turns many a wheel of industry, until finally the commerce of the nations is carried

by the mighty river of which it forms a part. Has it not filled a better rounded, more successful career than its brother starting in the woods yonder, who persisted in an independent course, who would carve out his own channel, and has ended in losing himself in the waste land, swallowed up by the sand, or making a swamp of what should be blessed by his absence?

The writer has had a prominent engineer say to him, that he would prefer a young man in his office who had no previous engineering study, to one with a diploma, because the former comes with nothing, whereas the latter has to be reconstructed, and unloaded of the impression that he knows how things should be done. This is certainly an extreme view to take, but it is one held in part by many engineers. None are more ready to help the young graduate who goes frankly and honestly to "learn the ropes" of the professional ship, and his college course is an immense accelerating force; but none are more disgusted with the man who does not know the topping-lift from the jib-boom, and yet expects to walk the quarter-deck.

These few remarks are suggested by a letter received by a committee of the Alumni Association of the School of Mines, whose aim is to establish a systematic method whereby engineers in active work, and those desiring positions, can be brought in communication. A scheme of that character will eventually be adopted, and will in due time appear in the QUARTERLY.

The letter was written by an engineer prominently identified with mining in the West, and as a portion of it is general in its interest and definite in character, it is appended hereto:

"My experience has led me from year to year to the firm conviction that there is nothing the young graduate needs so much as an opportunity to do practical work. I should consider it a great misfortune for any graduate who proposes to devote himself to his profession, to begin work in any other than a practical way.

"My own experience and observation have taught me that it is very difficult for a young graduate to obtain an opportunity to familiarize himself with practical work. This is partly owing to the fact that his services are, at first, of very little value, and perhaps, also, to the fact that he overvalues those services. I believe it to be far better for a graduate to commence working by the day, as a laborer, in almost any capacity, than as an assistant in the management, for by this means he becomes acquainted with his profession from the workman's standpoint, and also learns what to expect from the ordinary laborer. The necessity of spending a fixed amount of time in practical work each day, insures his being on the ground whenever emergencies arise, and in learning how they are met and overcome in ordinary daily work.

"I should say that many of the graduates of a school who would not be willing to place a new graduate without practical experience in a position of responsibility, would be glad to allow him to associate himself with technical operations, rendering such assistance as he could.

"My experience has been that there are always more places for trained men than there are men to fill them; but, in the West at least, when a man is wanted, the emergency is so great that no time can be had for practical training." **

The National Geographic Society of Washington:

In response to a circular which briefly stated that the advisability of the organization of a Geographic Society would be discussed, meetings were held in the Assembly Hall of the Cosmos Club, in Washington, D. C., on January 13th, 20th, and 27th, 1888, when the National Geographic Society was organized and incorporated, by-laws adopted, and officers elected.

The principal objects of this society are, to promote the increase and diffusion of geographic knowledge; to publish the transactions of the society, a magazine, and other works relating to the science of geography; to acquire a library, etc.

Nearly two hundred persons were enrolled at the first meeting as founders, and the following officers were elected for the ensuing year:

President.—Gardiner G. Hubbard.

Vice Presidents.—1. Land: H. G. Ogden, U. S. Coast Survey. 2. Sea: Commander J. R. Bartlett, U. S. Navy. 3. Climatology: General A. W. Greely, U. S. Army. 4. Life: C. Hart Merriam, Agricultural Department. 5. Geographic Art: Professor A. H. Thompson, U. S. Geological Survey.

Recording Secretary.—Henry Gannett, Chief Geographer, U. S. G. S.

Corresponding Secretary.—George Kennan.

Treasurer.—C. J. Bell.

Managers (8).—Cleveland Abbe, G. Brown Goode, W. B. Powell, J. C. Welling, Henry Mitchell, W. D. Johnston, Captain Birnie, and Marcus Baker—representing education, civil life, and the various scientific departments of the Government.

Each of the five Vice-Presidents represents in the society the department of geographic science printed opposite his name, and will present annually to the society an address, which shall be a summary of the work done throughout the world in his department during the year.

Papers have already been read before the society on the Physiography of the United States, by J. W. Powell; on Geography of the Argentine Republic, by W. Curtis; on the Physiographic Features of the Sea Bottom, by Captain J. R. Bartlett, and by others; and the society has in course of preparation a series of Atlases representing the Topography, Hydrography, Hypsometry, Climatology, Geology, Life Distribution, Cartography, etc., of the United States. H. M. W.

Metric Wire Gauge.

The National Electric Light Association, in convention assembled at Boston, on August 9th, 1887, issued a table of "mathematical properties of the Metric Wire Gauge" that indicates a practical step in the direction of the use of the Metric system in this country.

The table gives the following data:

Gauge number, nearest corresponding gauge number, in Brown and Sharp, and in Birmingham gauges; diameter in millimetres and in inches; sectional area in sq. millimetres and in sq. inches; logarithms of the sectional areas; square of gauge number; weight per length in both Metric and English units; length per weight in both Metric and English units; resistance in legal ohms of pure copper at 0° centigrade. **

Water Rams in Steam Pipes.

The principal cause of accidents in the operation of large, long steam pipes arises from the presence of water.

If steam be admitted at the top of a vessel partially filled with cold water, condensation will take place until the surface is somewhat heated, and this, in connection with a cloud which forms above the surface, will retard rapid condensation, so that in due time the full steam pressure can be maintained above water, cold at the bottom. This phenomenon is not an infrequent occurrence in boilers in which the circulation is defective. It is, therefore, perfectly safe to heat up any vessel containing cold water, if the steam can be admitted from the top upon the surface of the water, and so maintained. If, however, steam be blown in below the surface of the water, a bubble will be formed, which will increase in size until its surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, the bubble will collapse, and the water flowing in from all sides at high velocity will meet with a blow, forming what is called a water ram. In blowing into a large vessel, these explosions occur in the middle of the mass, and create simply a series of sharp noises. If, however, steam be blown into a large inclined pipe full of water, it will rise by difference of gravity to the top of the pipe, forming a bubble, as previously stated, and when condensation takes place the water below the bubble will rush up to fill the vacuum, giving a blow directly against the side of the pipe. As the water still further recedes, the bubble will get larger, and move farther and farther up the pipe, the blow each time increasing in intensity, for the reason that the steam has passed a larger mass of water, which is forced forward by the incoming steam to fill the vacuum.

The maximum effect generally takes place at a "dead end," as it is called, or where the end of the pipe is closed. Even if the water does not originally extend to the "dead end," if the pipe near it be once filled with steam which has bubbled through water on its way to that point, there may be sufficient cold metal to condense it, so that collapse will take place on the same principle as before, and the whole mass of water in the pipe be driven by the incoming current of steam against the end, sometimes with tremendous force, the effect being to cause leaks and sometimes rupture the pipe, or break out the end connections. It is not necessary, either, that the end of the pipe be closed. In fact, under certain conditions, a more forcible blow is struck when the end of the pipe is open, as, for instance, when a pipe crowned upward is is filled with water, one end being open and the steam introduced at the other. A bubble will in due time be formed at the top of the crown, when the water will be forced in by atmospheric pressure from one end, and by steam pressure from the other, and the meeting of the two columns frequently ruptures the pipe. Evidently, too, the same action can occur without difficulty in a level pipe, but, as previously stated, cannot in a pipe which descends away from the entering steam, so that the latter is *always above* the water.

It is evident from the above that it is always desirable in turning steam on an inclined main to introduce it from the top and let the water

out at the bottom of the slope. When this can be done, any workman can be trusted to attend to it. Frequently, however, there are undulations in the pipe, and at times mains which may contain water have to be heated by letting the steam in at the lower end. In a building, the difficulty, can, of course, be prevented by opening drip pipes at the lower end, and letting the water out before the steam is admitted. The same thing can be done with underground pipes, and provisions for this should always form part of the plans when it is known that a pipe will have to be heated up in this way. In practice, however, a street system contains so very many absolutely necessary details, that a provision of this kind will not be originally provided for, and at times it will occur that a main which it was expected to heat from the top of a slope may, from something being out of order, necessarily be heated from the other direction. Difficulties also occur in small pipes where the extra labor and expense required to provide special drains for overcoming this difficulty would not be warranted, particularly as another solution of the difficulty is available, even with pipes of considerable size.

If a blow-off opening be provided at one end of a main to be filled with steam, even if such blow-off be at the higher end, and the steam be admitted at the lower end, any water in the main can be driven out of the blow pipe, provided the steam valve be opened sufficiently wide to keep the pressure continuously maintained against the water. The explanation of this is that if the steam supply be limited, the water will run back under portions of the steam, forming bubbles which may suddenly collapse and produce water rams; but if the steam supply be practically unlimited, or at least sufficient, the steam will force the column of water back along the bottom of the pipe, as any vacuum formed will be filled by the steam driving back the water. There will be a series of small explosions, which will scarcely be heard, and do no harm, and the seething wall of water will be continually forced forward, and finally out of the pipe.

Note the distinction in the two methods of operation necessary to suit the conditions. When the steam is on top of the water, it may be turned on as slowly as desired, and it is better to turn it on slowly, as thereby the heavy castings are heated slowly and are not so liable to be strained; but when steam *must* be turned into the lower end of a descending pipe, which *may* be filled with water, the valve must be opened sufficiently to establish a definite current and keep up the pressure. This will not require the valve to be wide open, but the result will be substantially as though it were so open. The clearing of a pipe in this way requires nerve and judgment, but I have seen considerable cold water driven up hill out of a six-inch pipe, 1400 feet long, with a difference of elevation at the two ends of fully twenty feet, by letting steam in at the lower end and blowing the water out on the surface of the street through a two-inch blow-off pipe. The blow-off pipes are made no larger than this, even for mains fifteen and sixteen inches in diameter, but I do not consider that it would be safe to attempt to clear an ascending main of this size with this size of blow-off pipe. All these mains are more nearly level, have blow-offs at low points, near the valves, and can be blown off by putting steam in, at, or near the summit. In heating up an eleven-inch pipe, only 400 or 500 feet long, from the bottom, I

have had the flange taken off the extreme end in order to give the water free exit and prevent the possibility of a ram.—*From an Extract by the "Stevens Indicator," of a Lecture by Charles E. Emery.*

BOOK REVIEWS.

PRACTICAL PHYSICS FOR SCHOOLS. Vol. I. Electricity and Magnetism. Stewart and Gee. 218 pp. MacMillan & Co.

This little work is in great part an abstract of the larger book on *Elementary Practical Physics* written by the same authors. Quite a number of new and valuable features have been added, which increase the value of the work. The matter is well arranged, and the style is distinguished by the same clearness which renders the larger work so attractive. On account of the small size of the book, the treatment of the various subjects must, of necessity, be concise; but, at the same time, no sacrifice of important points has been made, and there is to be found within its few pages more valuable instruction than in many larger and more pretentious works. Bearing in mind the difficulty of obtaining the proper apparatus for the various experiments as described in the ordinary text-book, Messrs. Stewart and Gee have paid particular attention to the description of simple forms of apparatus, which can be easily constructed of cheap material by any one of ordinary mechanical skill. This is one of the most important features of the book. The introduction of an Appendix containing diagrams and descriptions of several typical physical laboratories, with instructions as to equipment, etc., is also a valuable feature. It is to be hoped that this little book will soon be followed by others of the same character, upon the subjects of Heat, Optics, Sound, etc. W. W. S.

Mr. C. Powell Karr, a graduate of School of Mines, Columbia College, has in preparation a Manual of American colleges, which proposes to give in classified form all the leading colleges, universities, technical and professional schools, their requirements for admission, courses of study, cost of tuition and living expenses, and, in a word, a systematic *résumé* of all the information needed by parents, guardians, and students to enable them to decide intelligently what college or institution of learning it is best to attend. It is to be issued from the press of William T. Comstock, New York.

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